Comfort Requirements for Industrial and None-Industrial Buildings & Radiant Floor Heating and Cooling Systems

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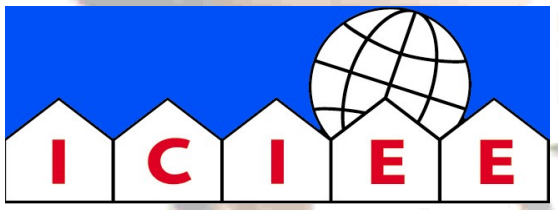
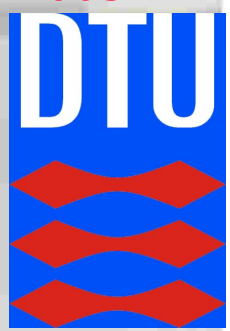




COMFORT-PRODUCTIVITY
Building costs

People	100
Maintenance	10
Financing	10
Energy	1

INDOOR ENVIRONMENT

- THERMAL
- AIR QUALITY
- ACOUSTIC
- LIGHT

THERMAL ENVIRONMENT

- ISO EN 11399 Principles and application of international standards
- ISO EN 13731 Definitions, symbols and units
- ISO EN 7730 Moderate thermal environments: determination of PMV and PPD indices and specification of the conditions for thermal comfort.
- ISO EN 7933 Hot environments: analytical determination and interpretation of thermal stress using calculation of required sweat rate
- ISO EN 7243 Hot environments: estimation of the heat stress on working man, based on the WBGT index (wet bulb globe temperature)
- ISO TR 11079 Evaluation of cold environments: determination of required clothing insulation (IREQ)
- ISO EN 8996 Determination of metabolic rate
- ISO EN 9920 Estimation of the thermal insulation and evaporative resistance of a clothing ensemble
- ISO EN 7726 Instruments and methods for measuring physical quantities (under revision)
- ISO EN 10551 Assessment of the influence of the thermal environment using subjective judgement scales.
- ISO 9886 Evaluation of thermal strain by physiological measurements
- ISO DIS 12894 Medical supervision of individuals exposed to extreme hot or cold environments
- ISO CD 14415 Application of international standards for people with special requirements
- ISO NP 13732 Method for the assessment of human responses to contact with surfaces
  - Part 1 Hot surfaces
  - Part 2 Moderate surfaces
  - Part 3 Cold surfaces
- ISO NP 15265 Risk of stress or discomfort in thermal working environments
- ISO/NP 14505 Evaluation of the thermal environment in vehicles

MODERATE THERMAL ENVIRONMENT

- **ISO EN 7730**
  - Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort effects.
- **ASHRAE 55-2004**
  - Thermal environment conditions for human occupancy
- **CR 1752**
  - Ventilation of buildings-Design criteria for the indoor environment

MODERATE ENVIRONMENTS

- **GENERAL THERMAL COMFORT**
  - **PMV / PPD, OPERATIVE TEMPERATURE**
- **LOCAL THERMAL DISCOMFORT**
  - **Radiant temperature asymmetry**
  - **Draught**
  - **Vertical air temperature difference**
  - **Floor surface temperature**

GENERAL THERMAL COMFORT

- **Personal factors**
  - Clothing
  - Activity
- **Environmental factors**
  - Air temperature
  - Mean radiant temperature
  - Air velocity
  - Humidity

GENERAL THERMAL COMFORT

Type of building/ space	Clothing Cooling season (summer) clo	season (winter) clo	Activity met	Category	Operative Temperature Cooling season (summer) °C	Heating season (winter) °C
Office	0,5	1,0	1,2	A	24.5 ±0.5	22.0 ±1.0
				B	24.5 ±1.5	22.0 ±2.0
				C	24.5 ±2.5	22.0 ±3.0
Cafeteria/ Restaurant	0,5	1,0	1,4	A	23.5 ±1.0	20.0 ±1.0
				B	23.5 ±2.0	20.0 ±2.5
				C	23.5 ±2.5	20.0 ±3.5
Department Store	0,5	1,0	1,6	A	23.0 ±1.0	19.0 ±1.5
				B	23.0 ±2.0	19.0 ±3.0
				C	23.0 ±3.0	19.0 ±4.0

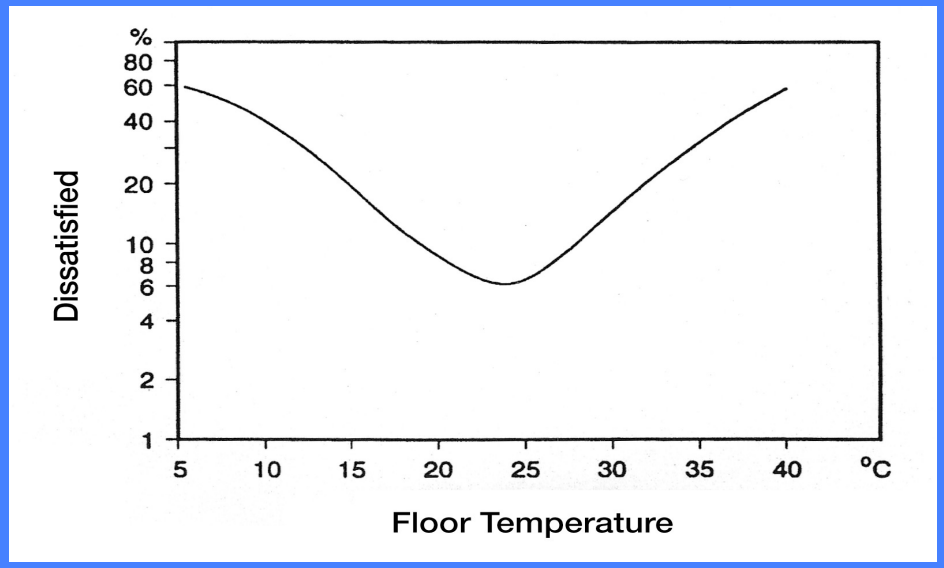
LOCAL THERMAL DISCOMFORT

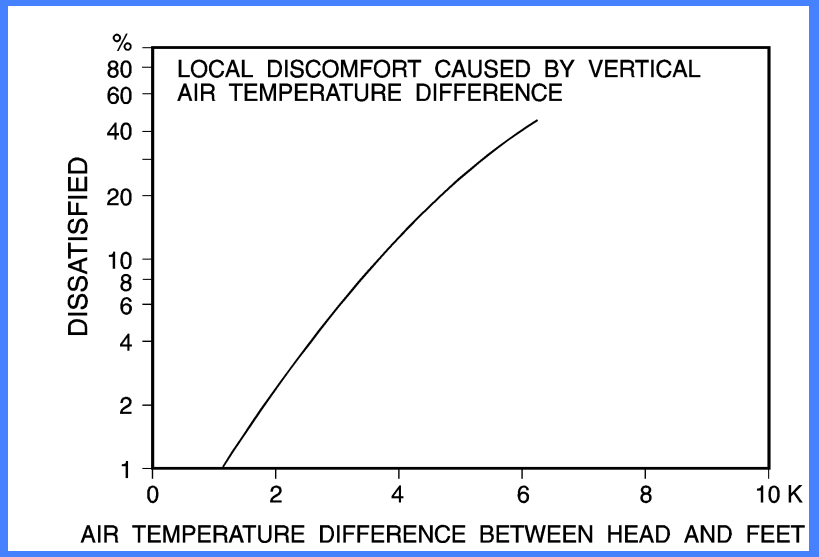
- FLOOR SURFACE TEMPERATURE
- VERTICAL AIR TEMPERATURE DIFFERENCE
- DRAUGHT
- RADIANT TEMPERATUR ASYMMETRI

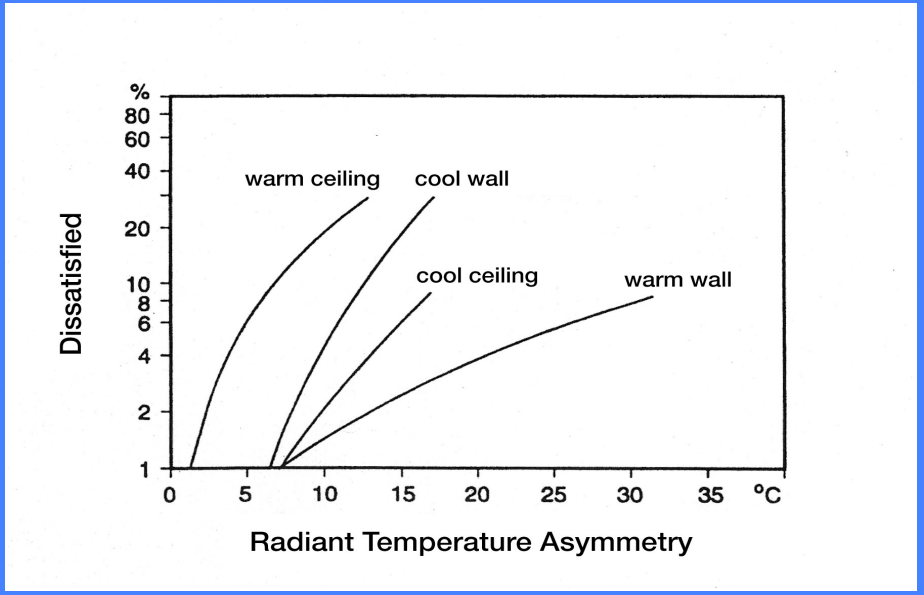
DRAUGHT

- DRAUGHT RATING, DR
- MEAN AIR VELOCITY
- TURBULENCE
- AIR TEMPERATURE

$$DR = (34 - t_a)(v - 0.05)^{0.62}(0.37\ v\ Tu + 3.14)$$







LOCAL THERMAL DISCOMFORT

RADIANT TEMPERATURE ASYMMETRY

- **HEATED CEILING: < 5 °C**
- **COOLED CEILING: < 14 °C**
- **WARM WALL: < 23 °C**
- **COOL WALL: <10 °C**

VENTILATION AND IAQ STANDARDS OR GUIDELINES

- CR1752
- prEN13779
- ASHRAE 62.1
- ASHRAE 62.2
- ISO/TC205 WG4

VENTILATION

- COMFORT
- HEALTH

INDOOR CONTAMINANTS

- People and their activity (smoking)
- Building
- Furnishing
- HVAC system
- Outdoor

Concept for calculation of design ventilation rate

People Component

Building Component

Design Outdoor Air Ventilation Rate

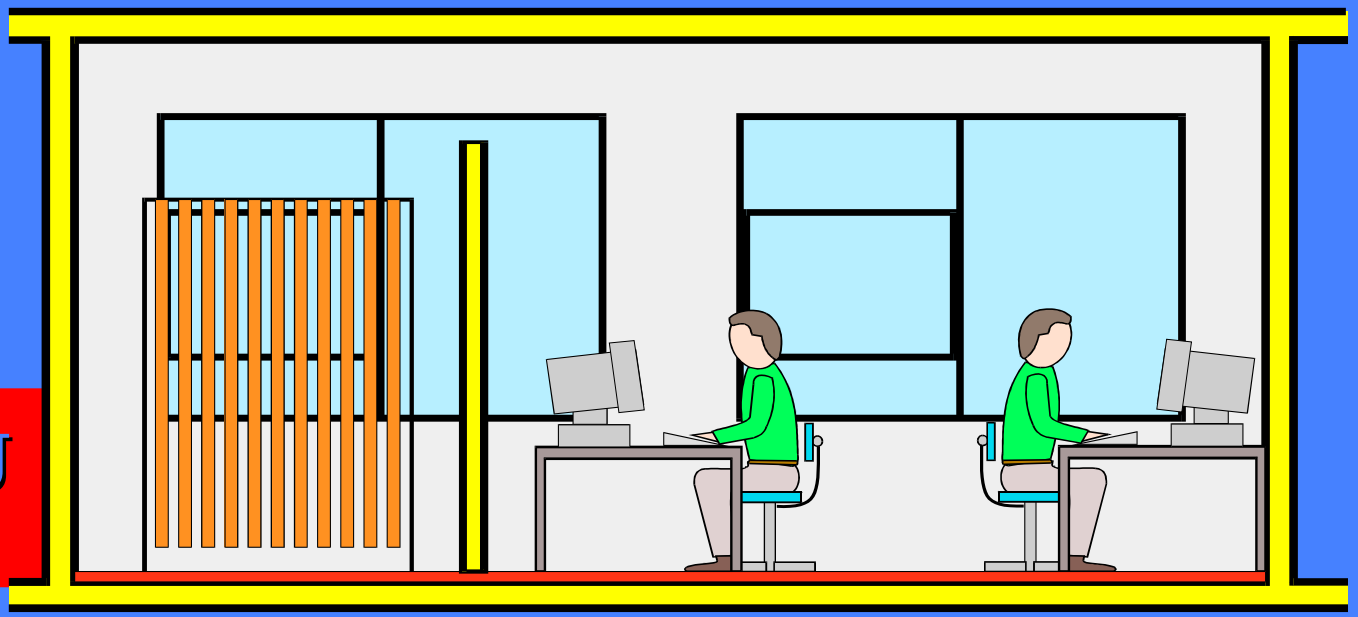
= **RbAb** **RpPd** **+** **RsSd** **+**

- Minimum l/s/Person
- Number of People
- Ventilation per Smoker
- Number of Smokers
- Building Area
- Minimum l/s/m²

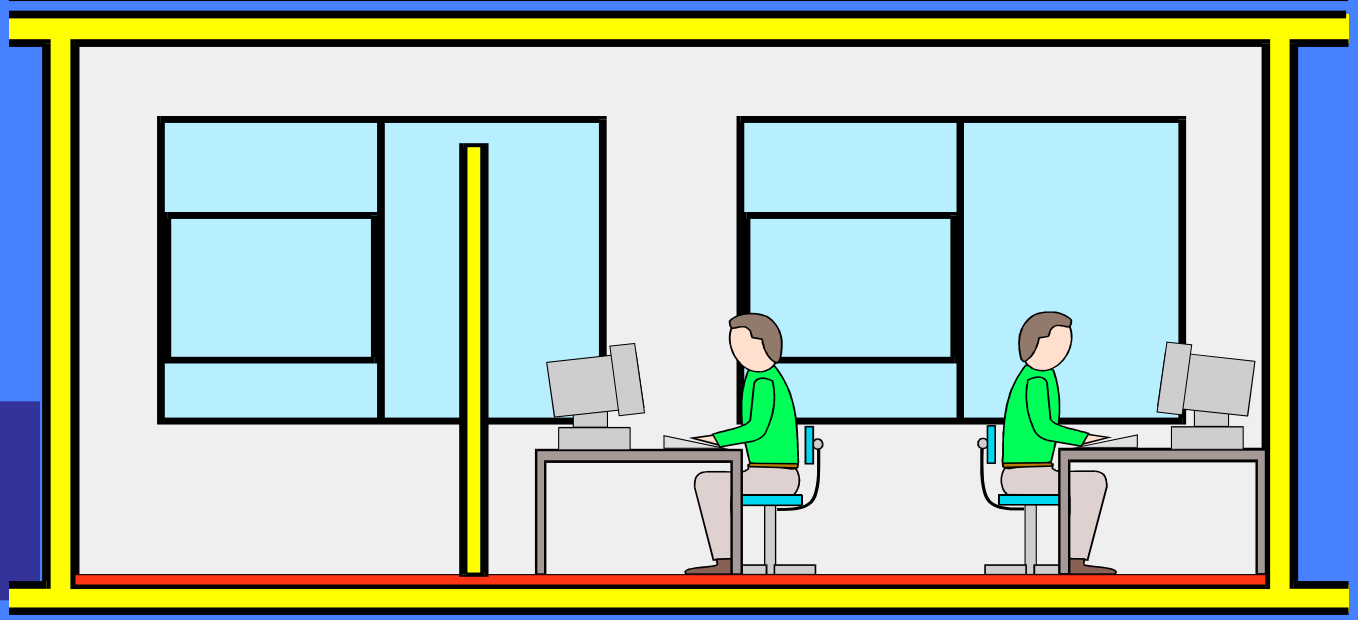
Type of building/ space	Occu-pancy Per-son/m^2	Cate-gory 1752	Minimum ventilation rate, i.e. for occupants only l/s person		Additional ventilation for building (add only one) l/s·m^2			Total l/s·m^2	
			Ashrae R_p	CEN	CEN low-polluting building[1)]	CEN not low-polluting building	Ashrae R_a	CEN Low Pol.	Ashrae
Single office (cellular office)	0,1	A	2,5	10	1,0	2,0	0,3	2	0,55
		B		7	0,7	1,4		1,4	
		C		4	0,4	0,8		0,8	
Land-scaped office	0,07	A	2,5	10	1,0	2,0	0,3	1,7	0,48
		B		7	0,7	1,4		1,2	
		C		4	0,4	0,8		0,7	

Method

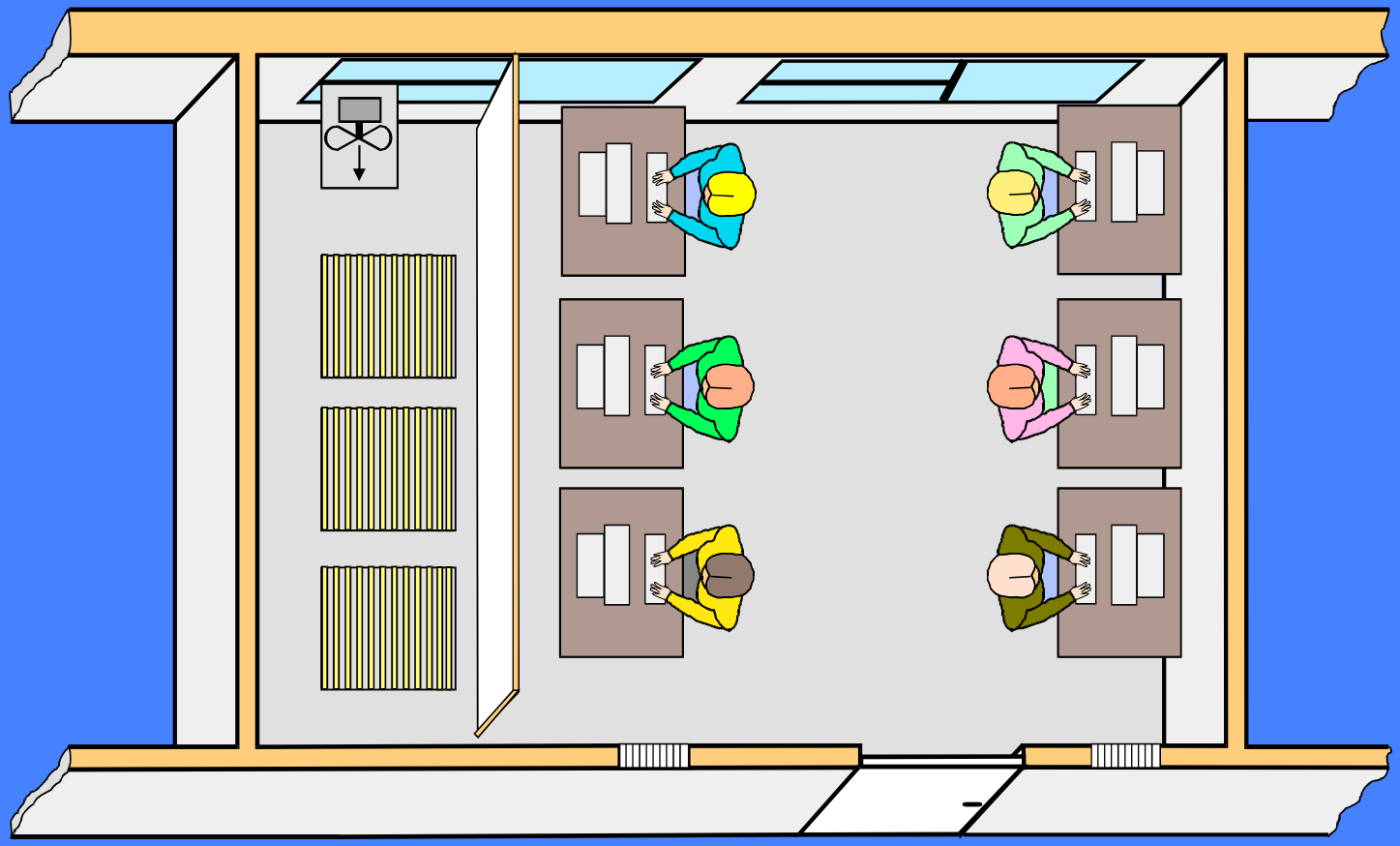
Non-low-polluting building



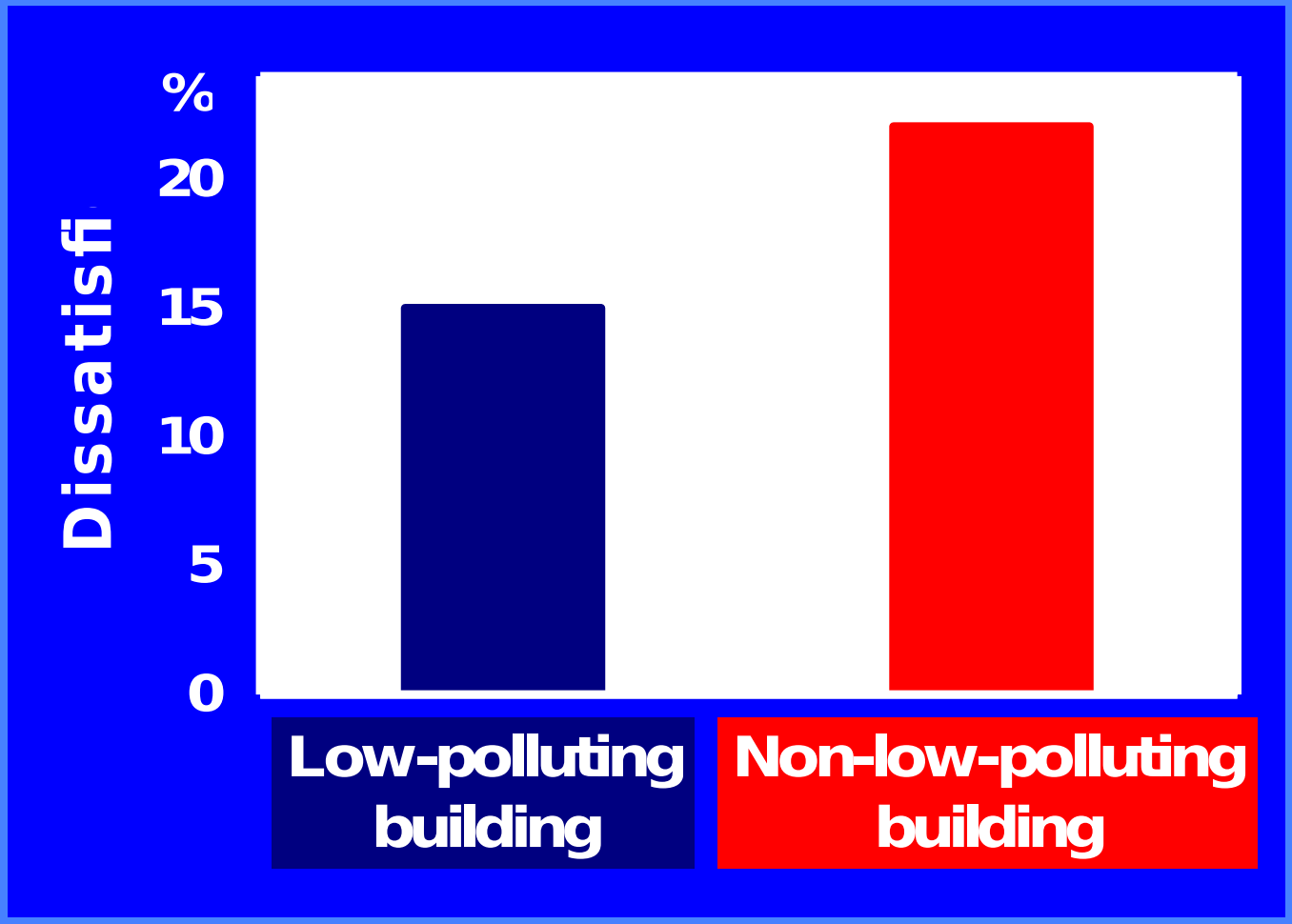
Low-polluting building



Experimental set-up



Perceived air quality



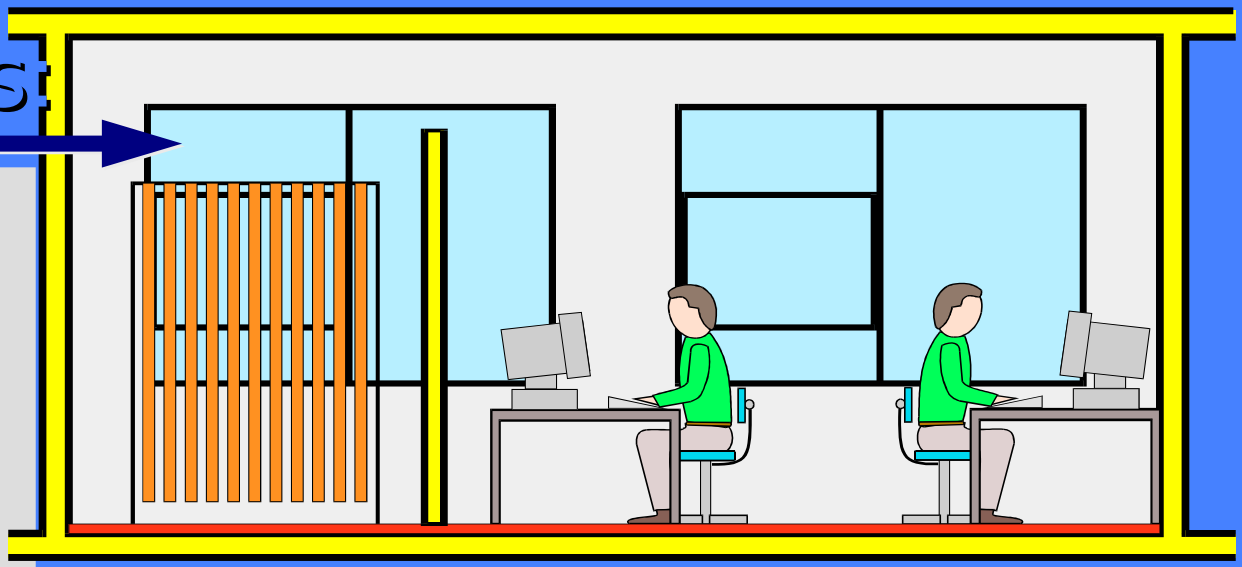
Methods

Outdoor air rates:

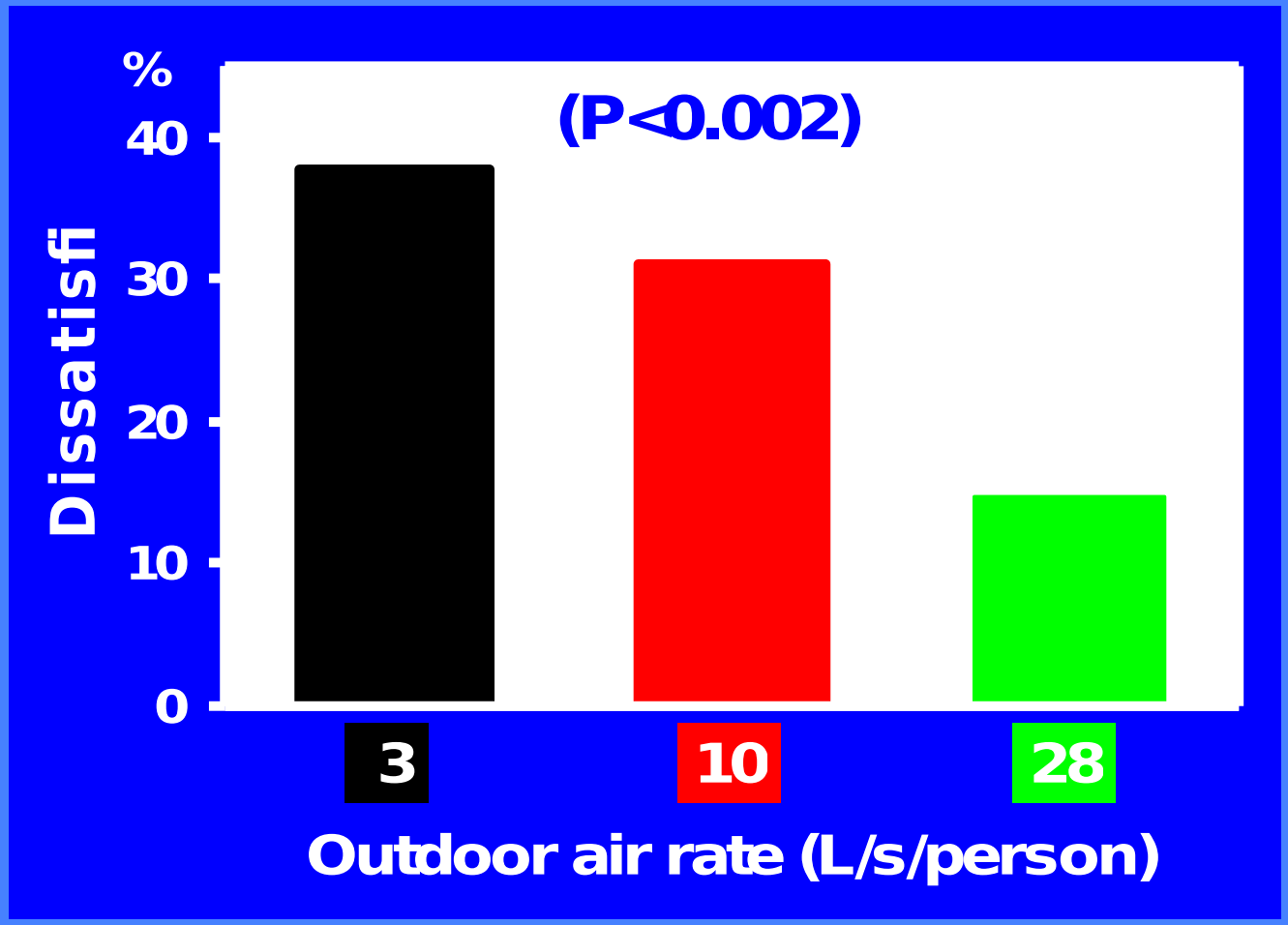
3 L/s/person (0.6 h^{-1})

10 L/s/person (2 h^{-1})

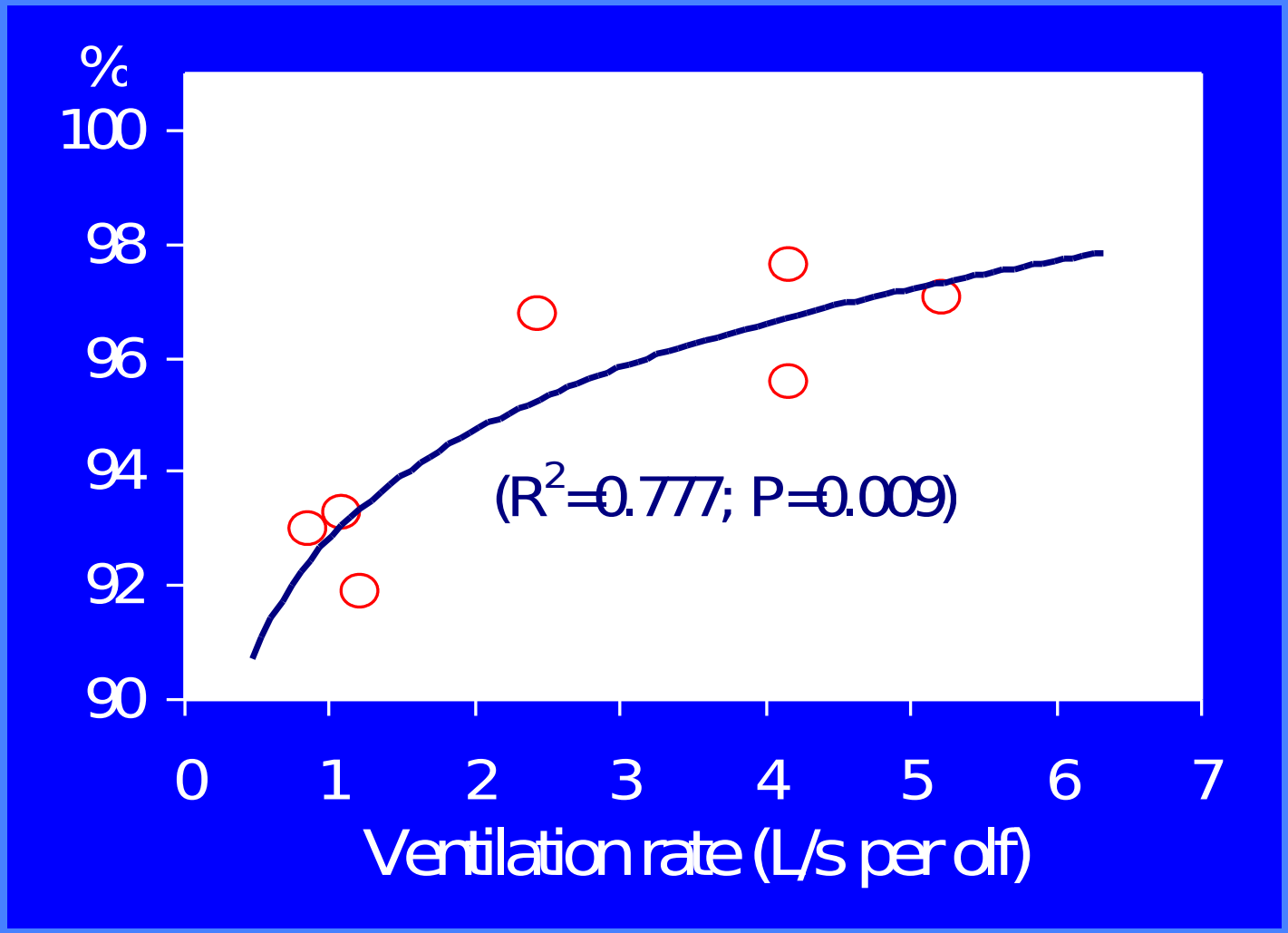
30 L/s/person (6.0 h^{-1})



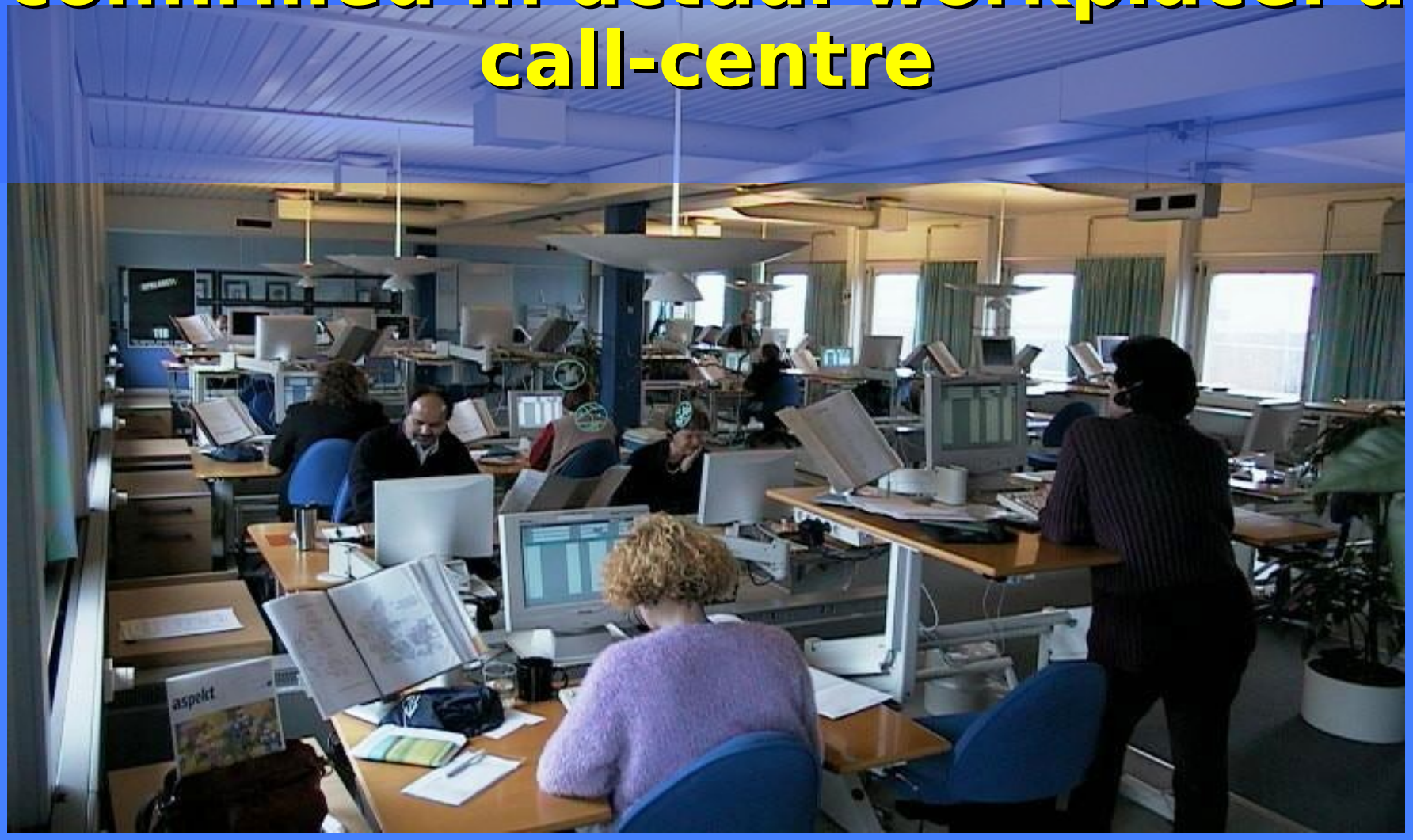
Perceived air quality



Total productivity



The results of these studies were confirmed in actual workplace: a call-centre



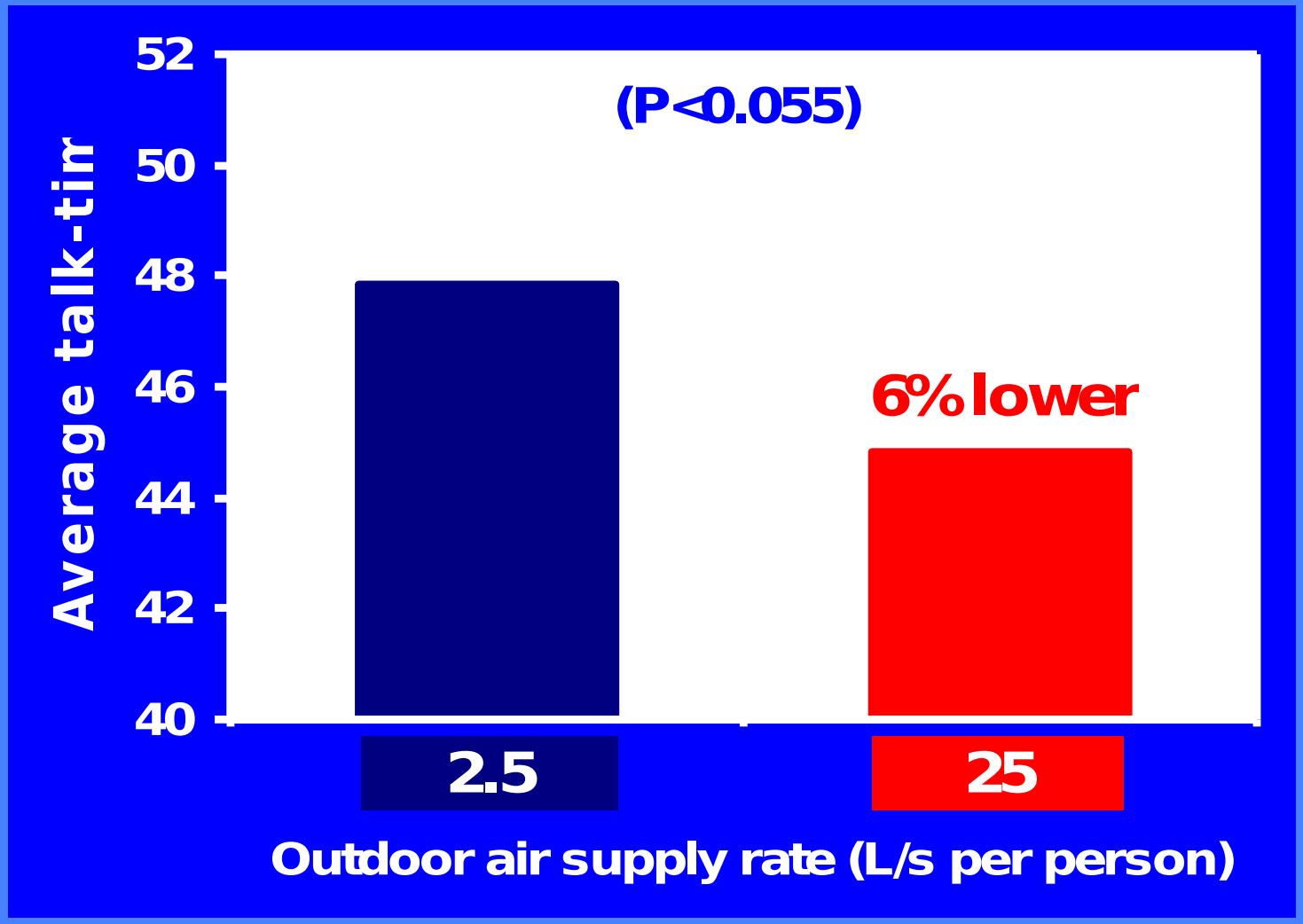
Interventions to air quality

- 6-month old used filter changed for new one
- Outdoor air supply rate increased 10 times from 2.5 to 25 L/s per person

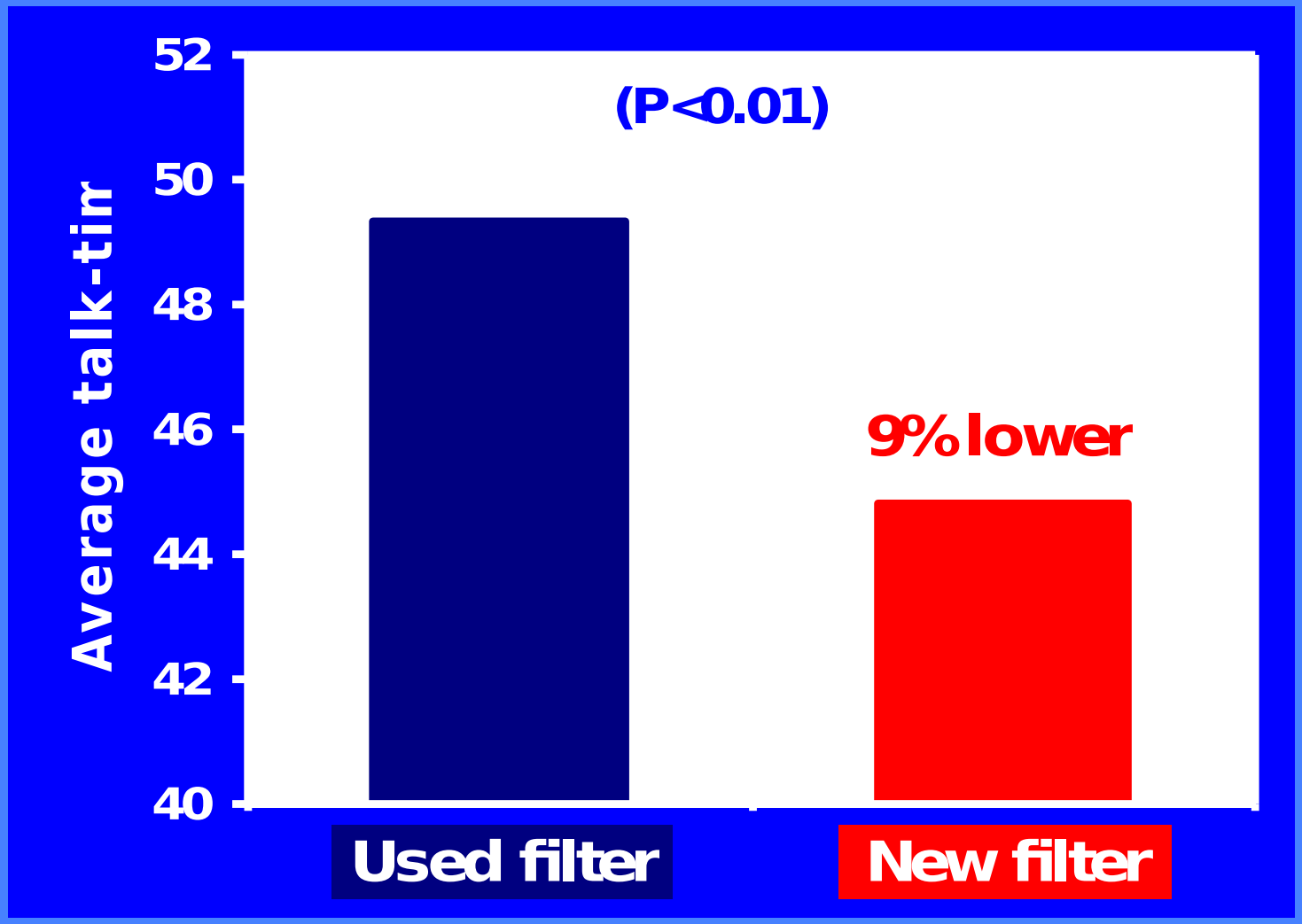
Performance measure

$$\text{Average talk time} = \frac{\text{Talk time}}{\text{Number of calls}}$$

Average talk-time with NEW FILTER

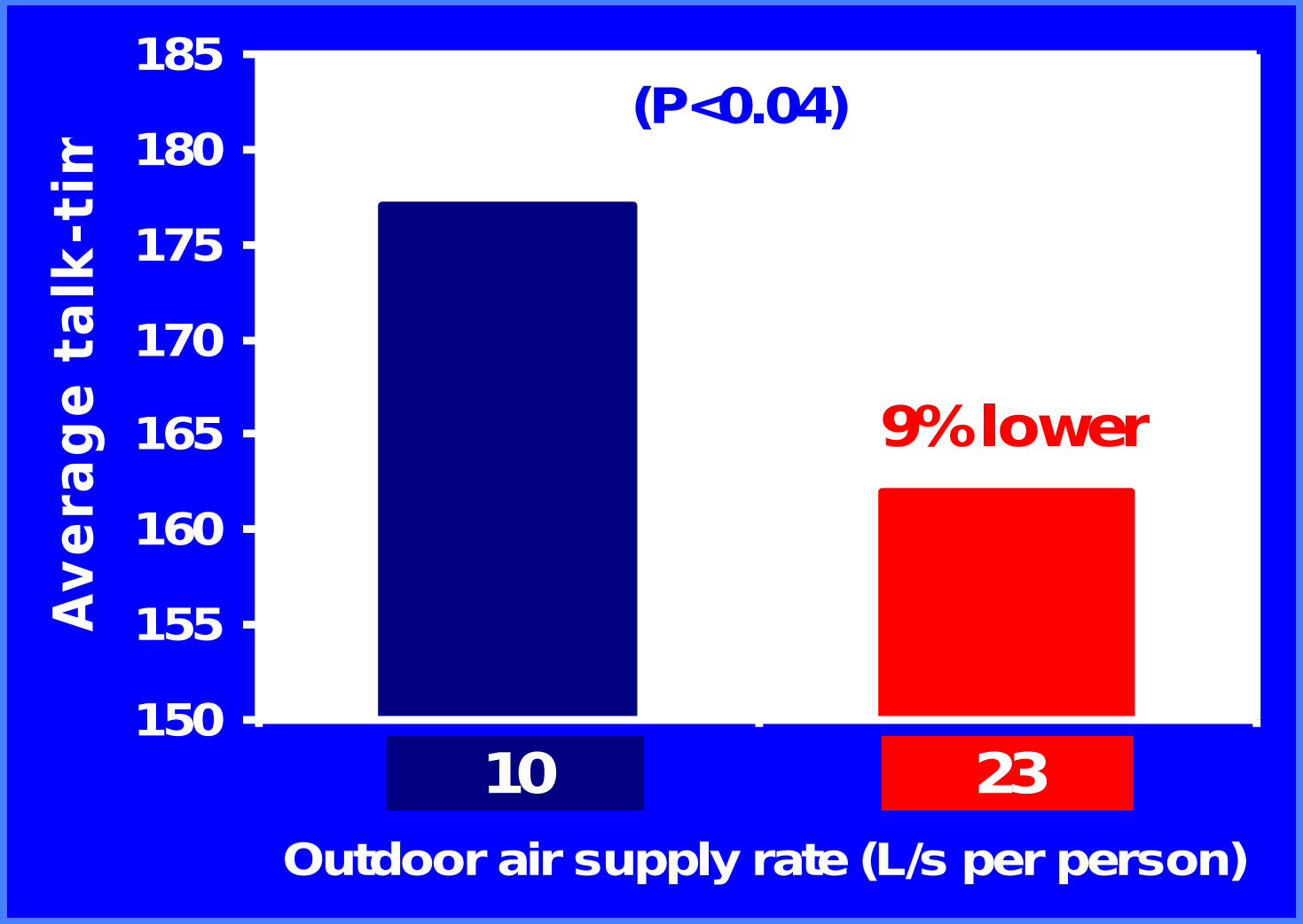


Average talk-time with HIGH OUTDOOR AIR RATE

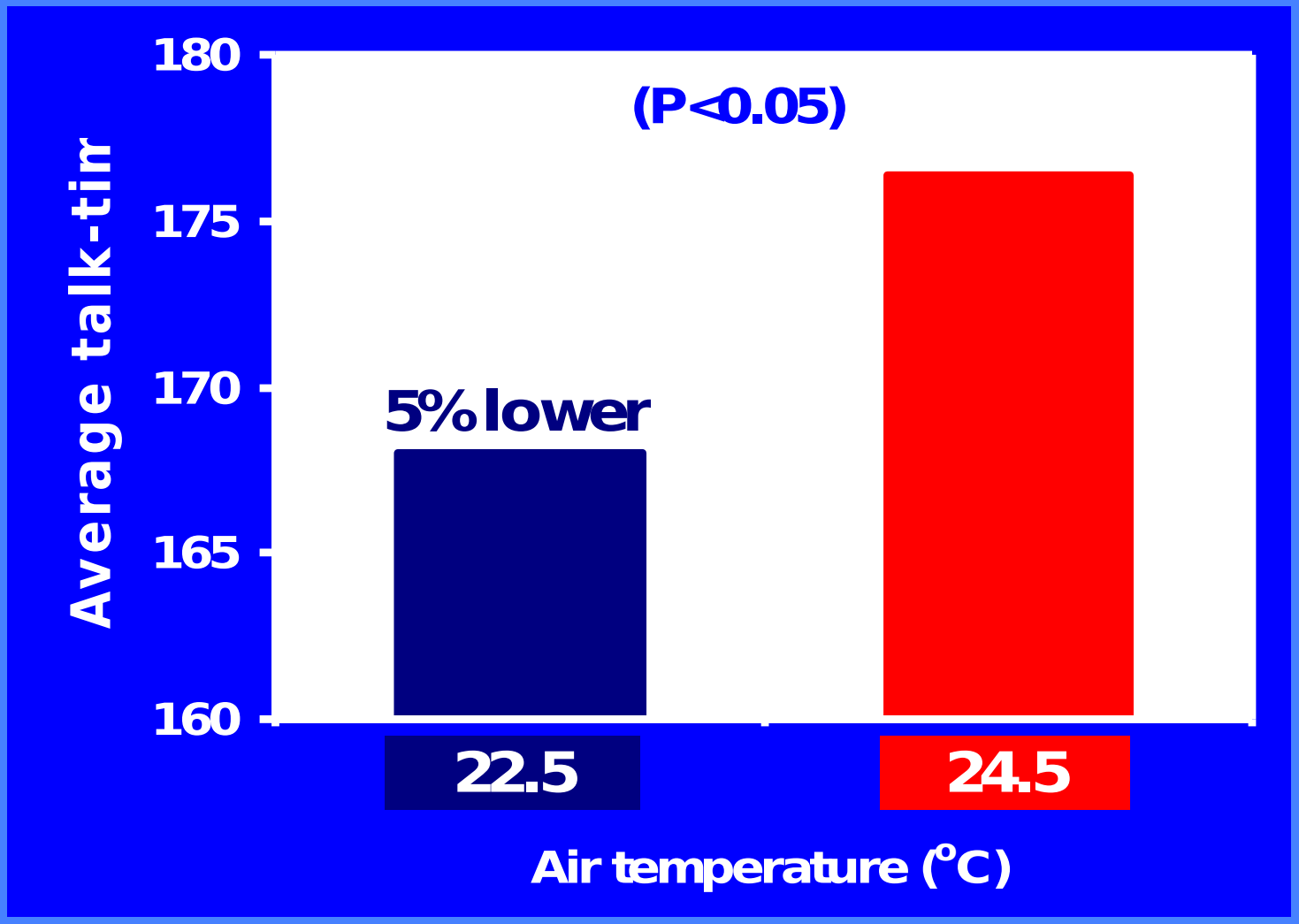


This study has been repeated in another country (Singapore) with similar results

Average talk-time at AIR TEMPERATURE 24.5°C

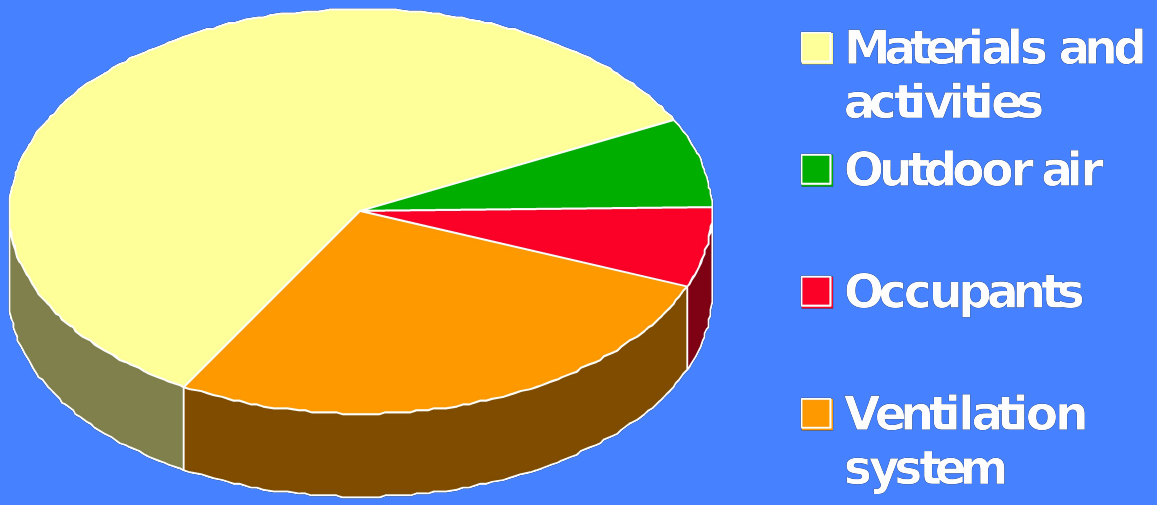


Average talk-time with LOW OUTDOOR AIR RATE



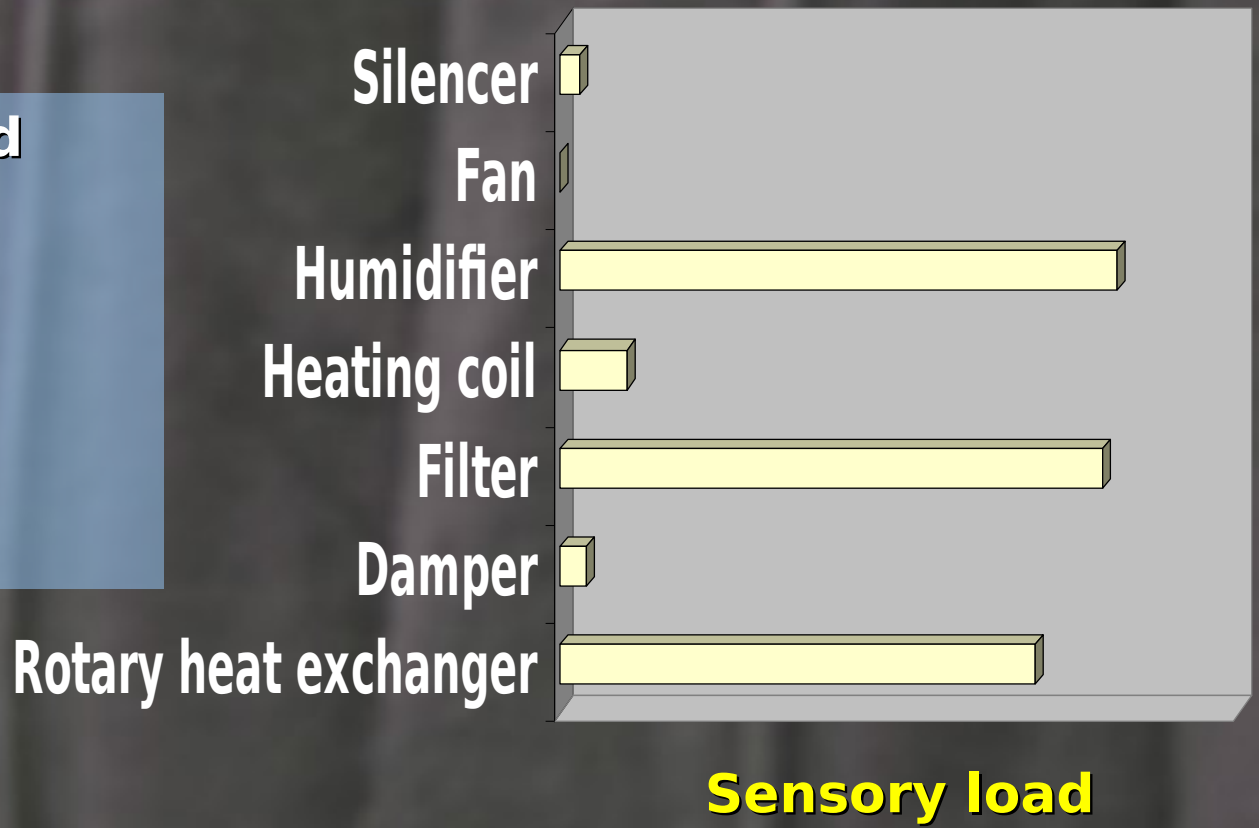
European Audit Project to Optimise Indoor Air Quality and Energy consumption in Office Buildings

Sensory pollution load



Sensory pollution sources in HVAC systems

- **8 systems investigated**
- **2 – 16 years old**
- **500 – 29000 m^3/h**



Source: Pejtersen et al, 1989

HYDRONIC RADIANT HEATING AND COOLING
WHY?

- Water based systems
- More economical to move heat by water:
  - Greater heat capacity than air
  - Much smaller diameter pipes than air-ducts
  - Electrical consumption for circulation pump is lower than for fans
- Lower noise level
- Less risk for draft
- Lower building height
- Higher efficiency of energy plant

CONCEPTS OF RADIANT HEATING AND COOLING SYSTEMS

- Heating - cooling panels
- Surface systems
- Embedded systems

Suspended cooled ceilings

Bild 21 Metallsegel, sichtseitig

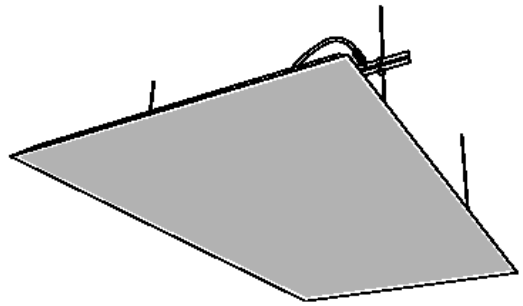
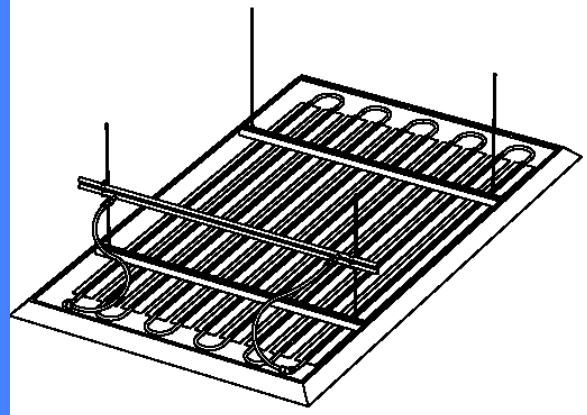
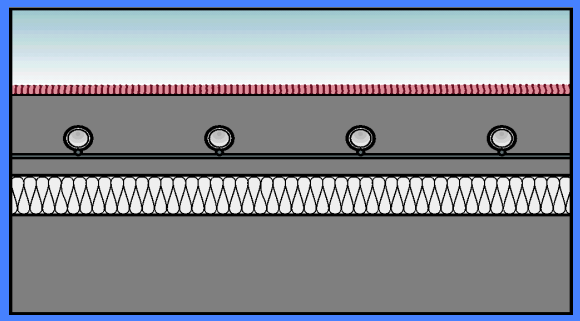


Bild 22 Metallsegel, Kühltechnik

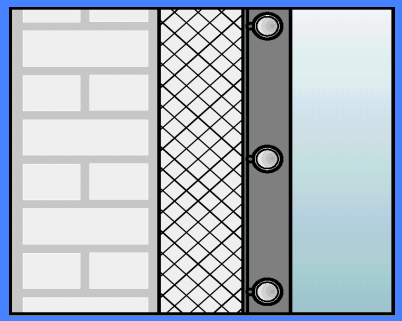


Radiant surface heating and cooling systems

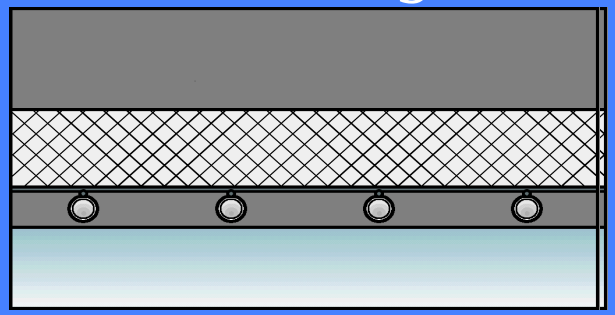
Floor



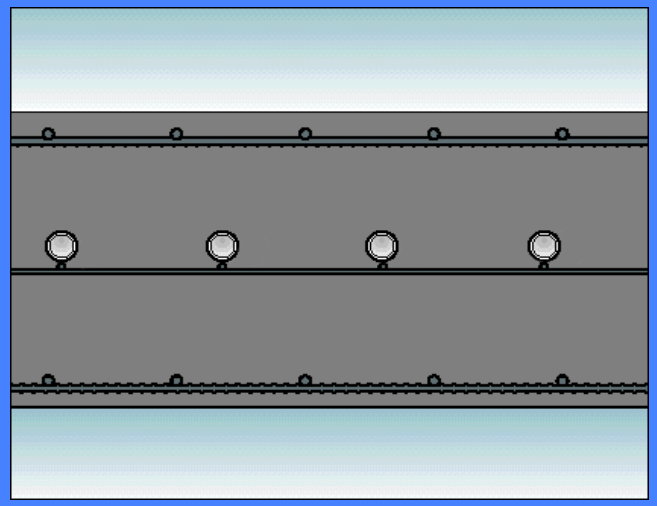
Wall

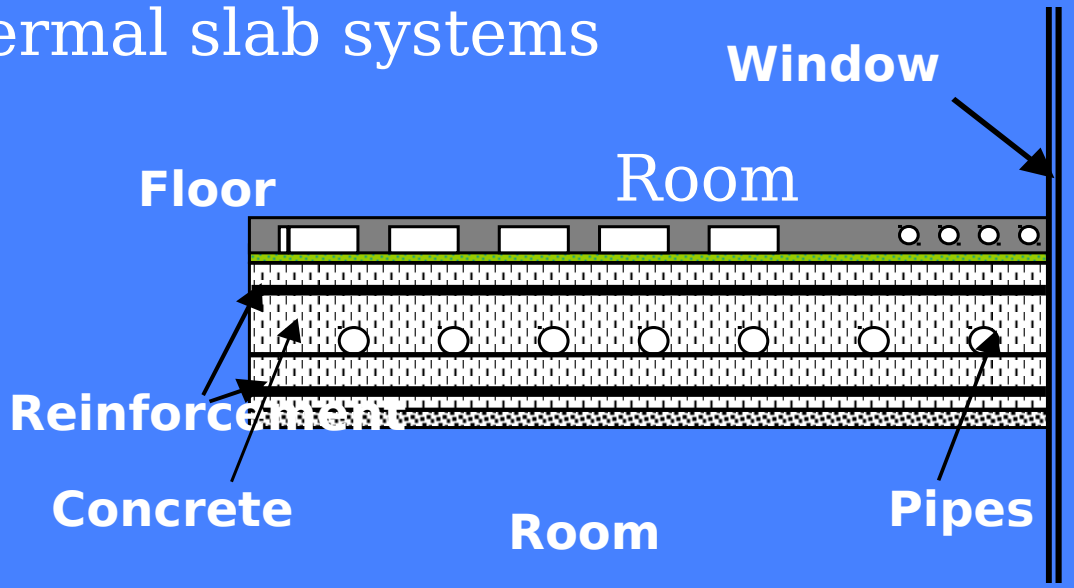


Ceiling



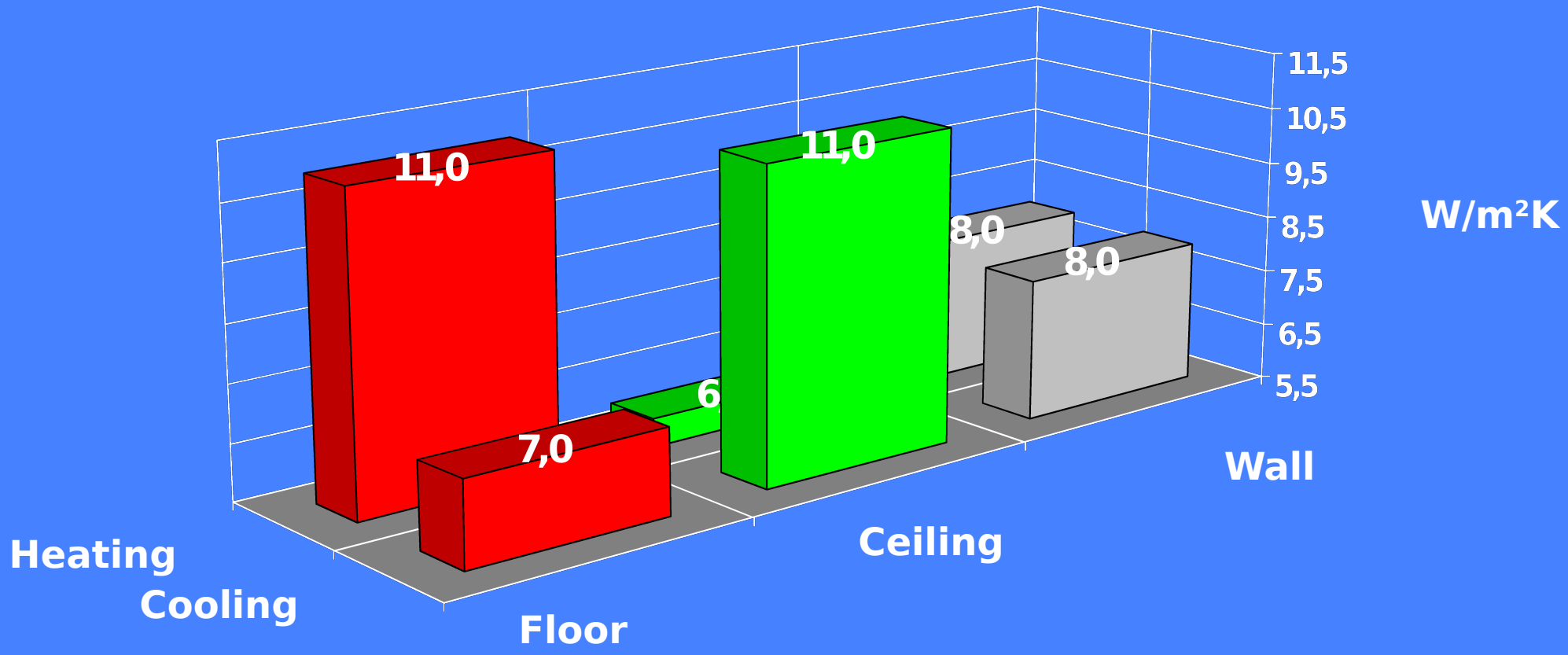
Activated thermal slab systems



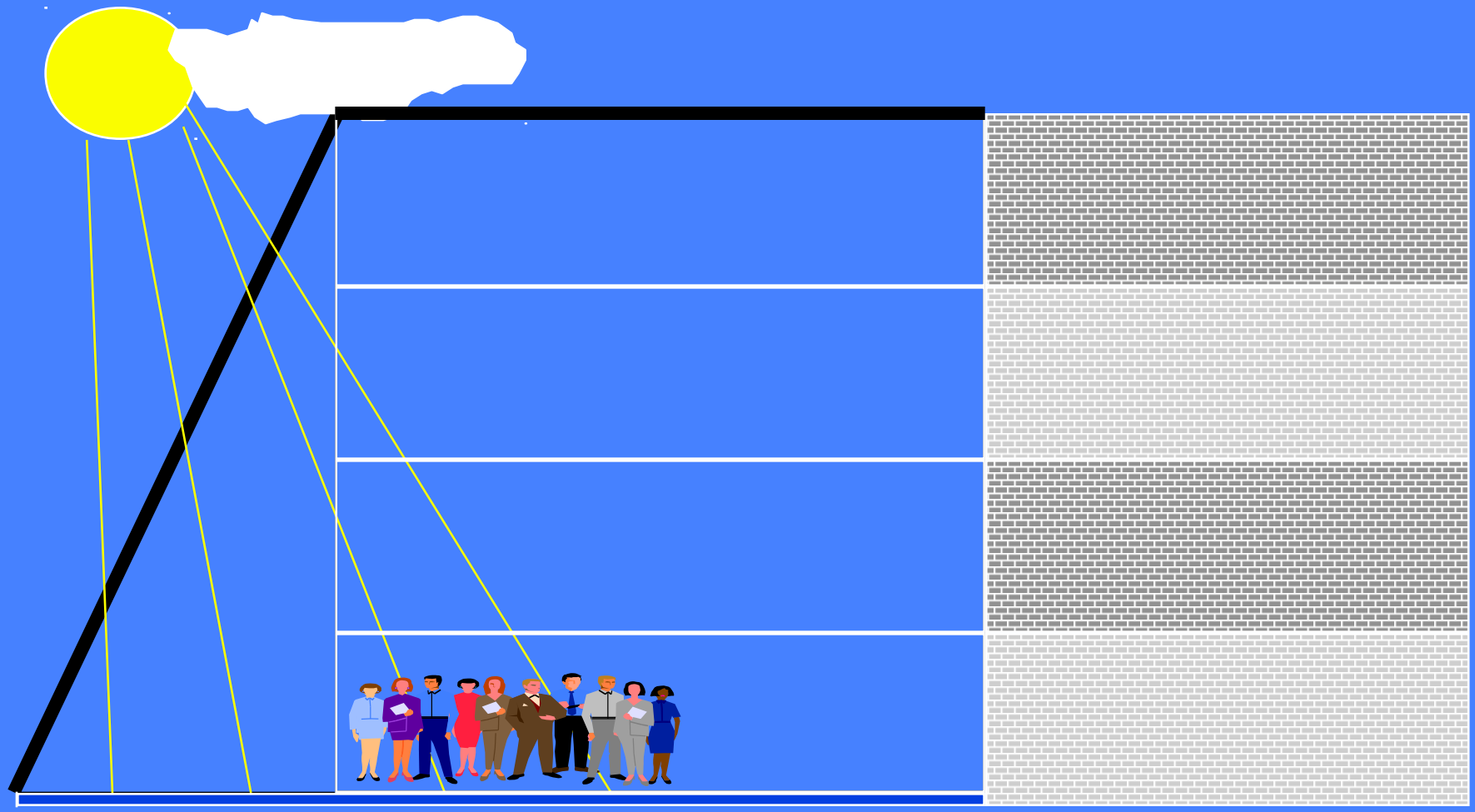


SURFACE HEATING AND COOLING

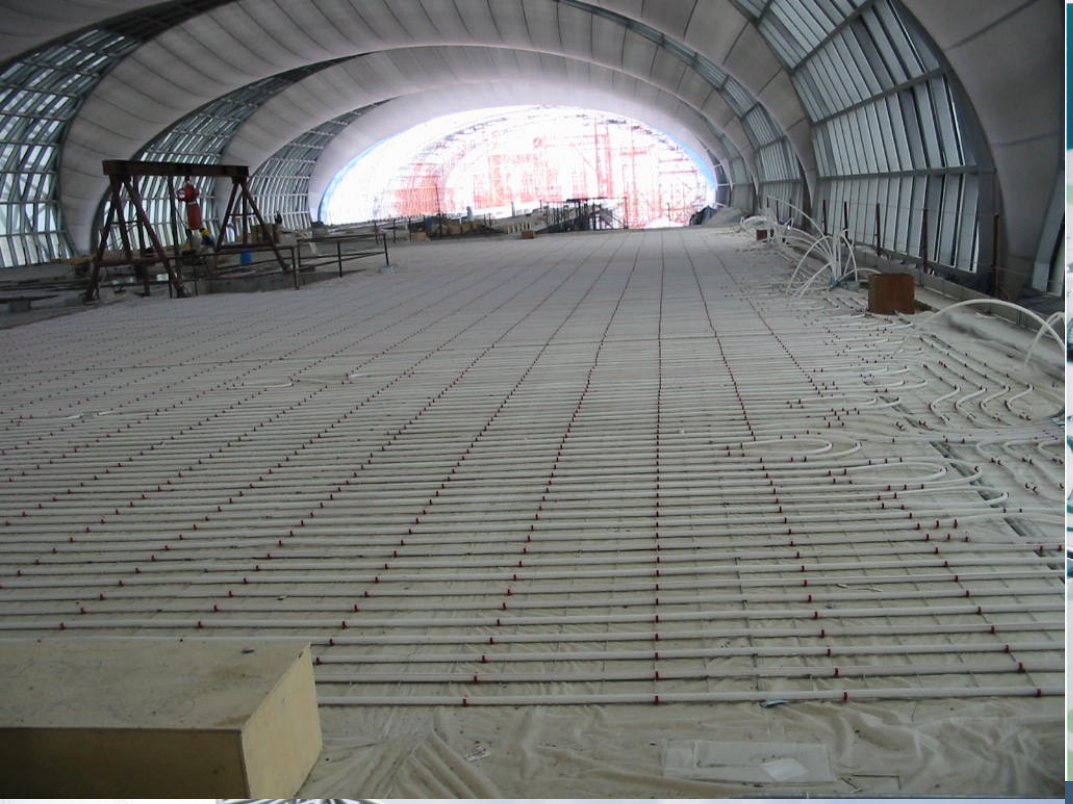
Heat transfer coefficient

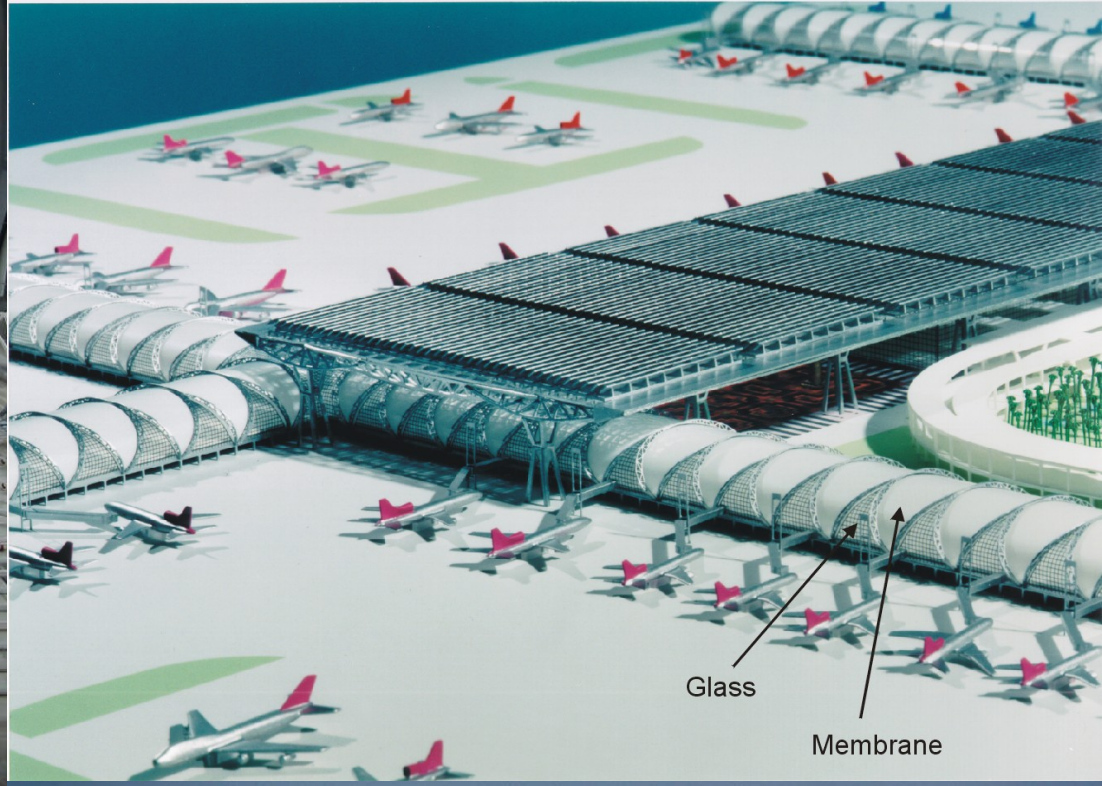


RADIANT FLOOR COOLING

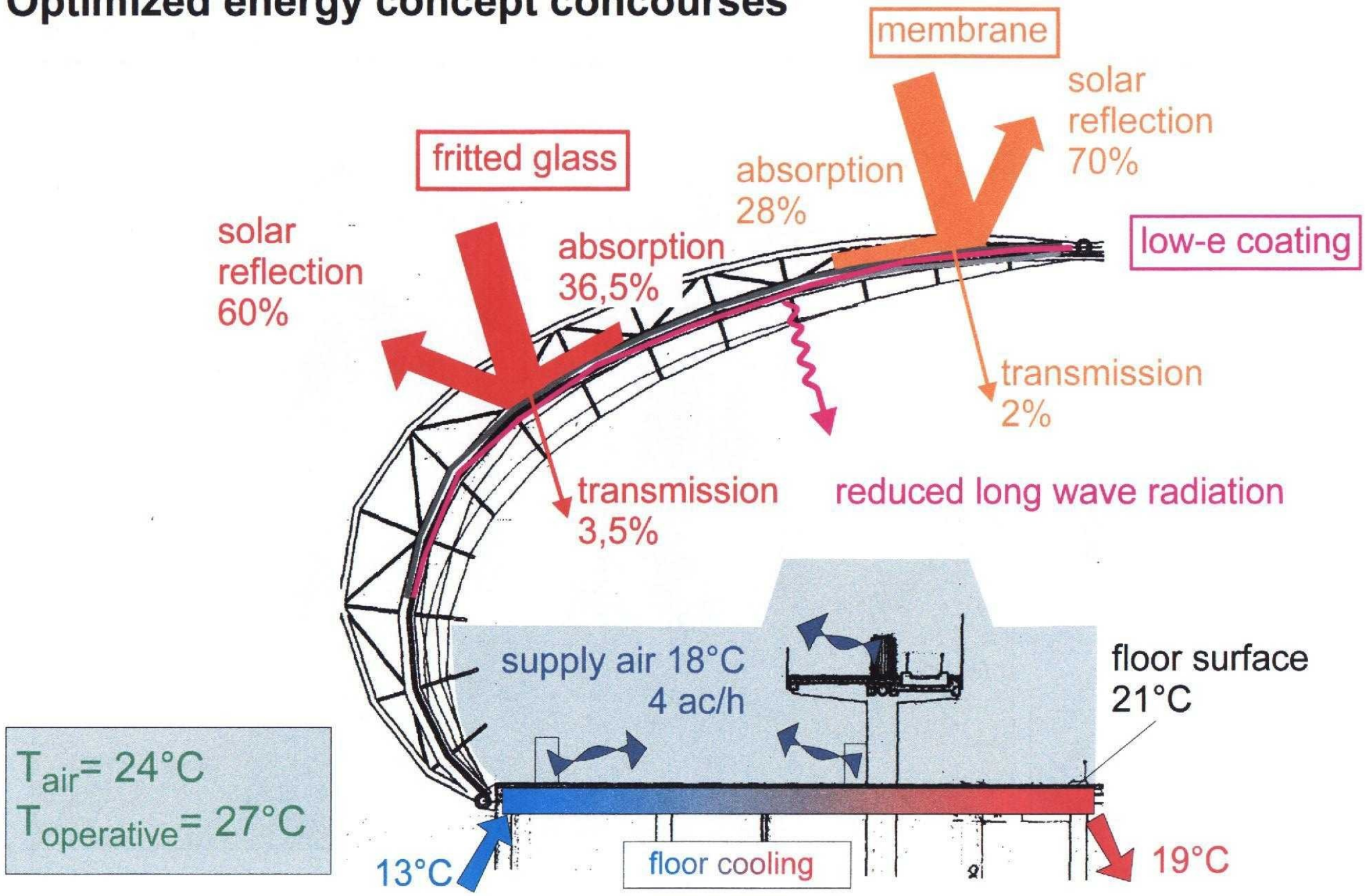


Airport Bangkok



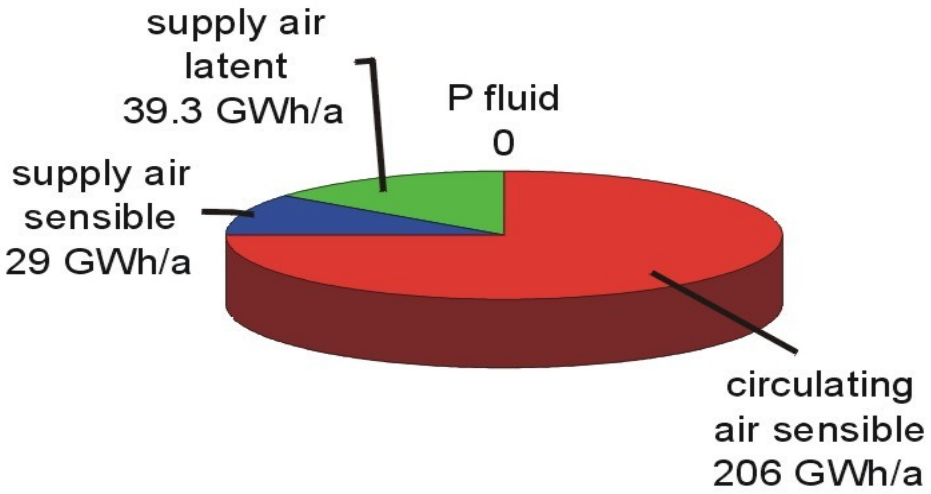

Glass
Membrane

Optimized energy concept concourses



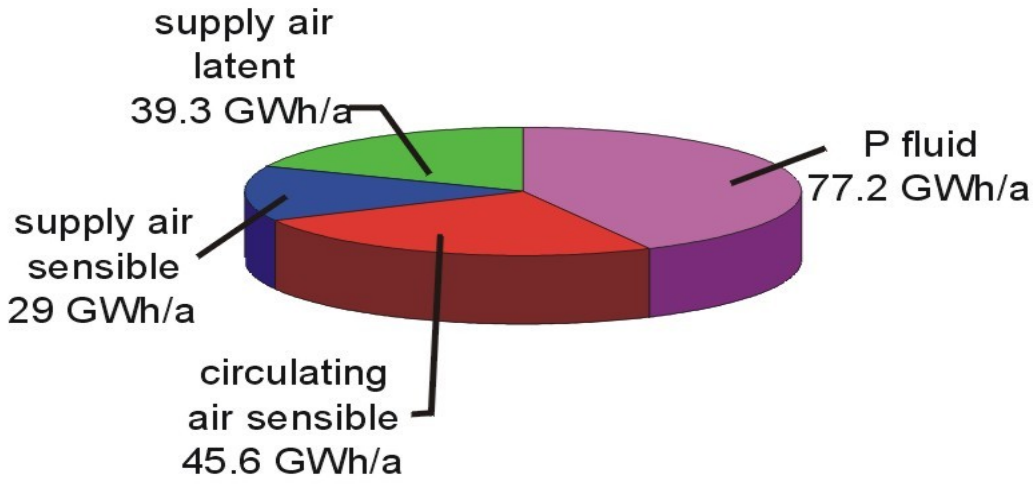
Comparison of Cooling loads entire Airport

Original Concept



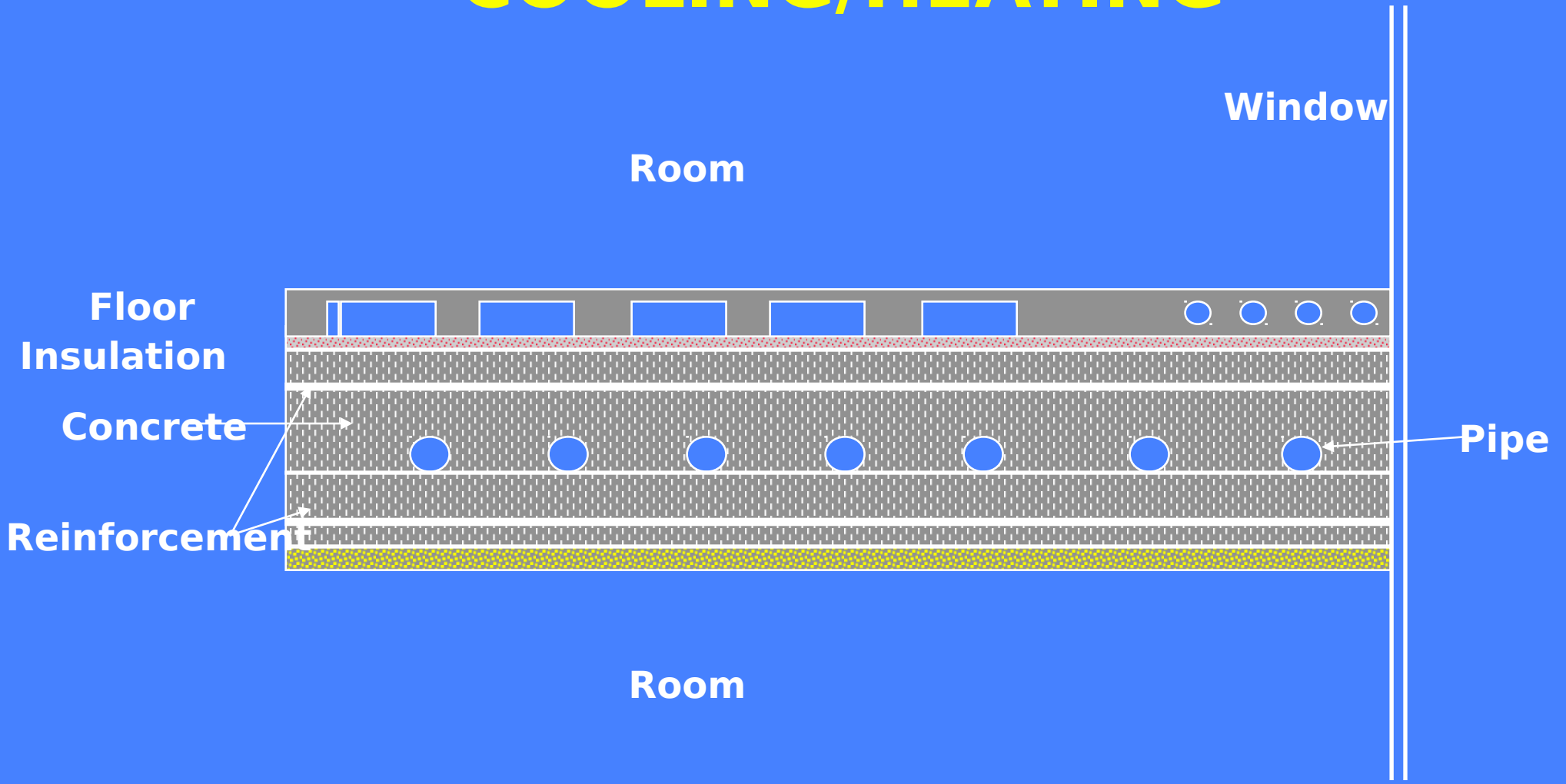
total load: 275 GWh/a
739 kWh/m²a

Optimized Concept

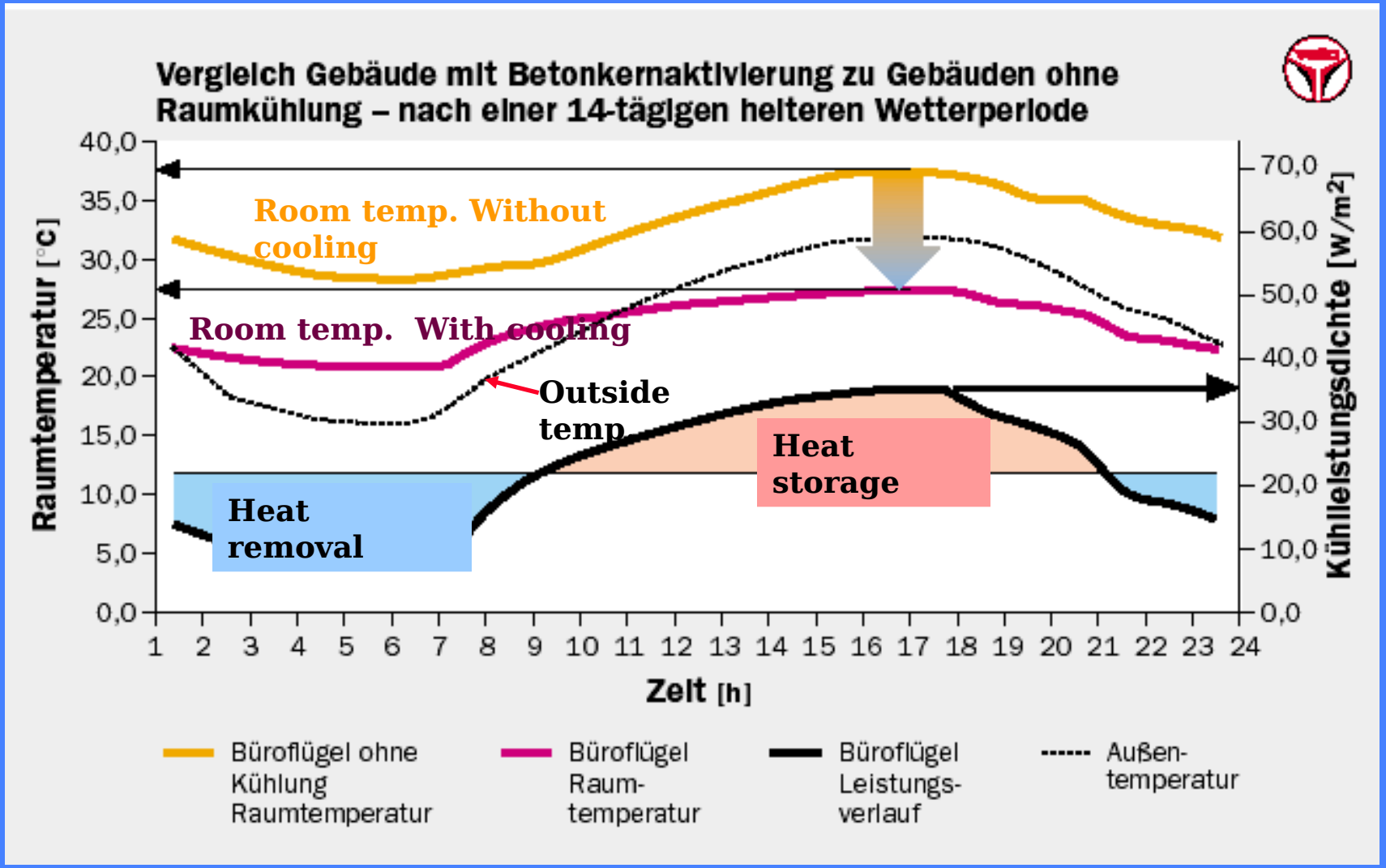


total load: 191 GWh/a
513 kWh/m²a

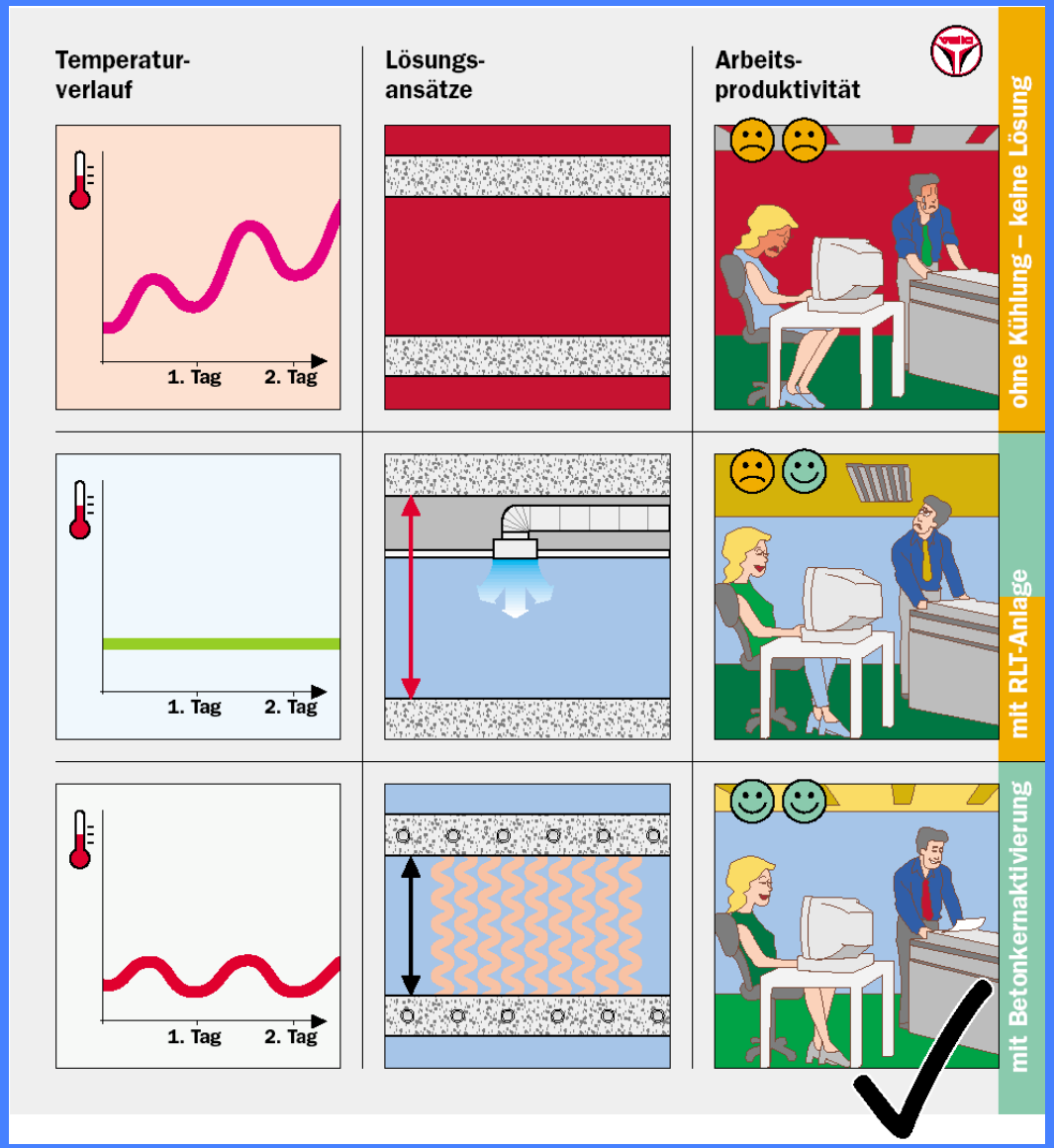
CONCRETE SLAB COOLING/HEATING



Concept of activated thermal slab system



COMFORT-PERFORMANCE

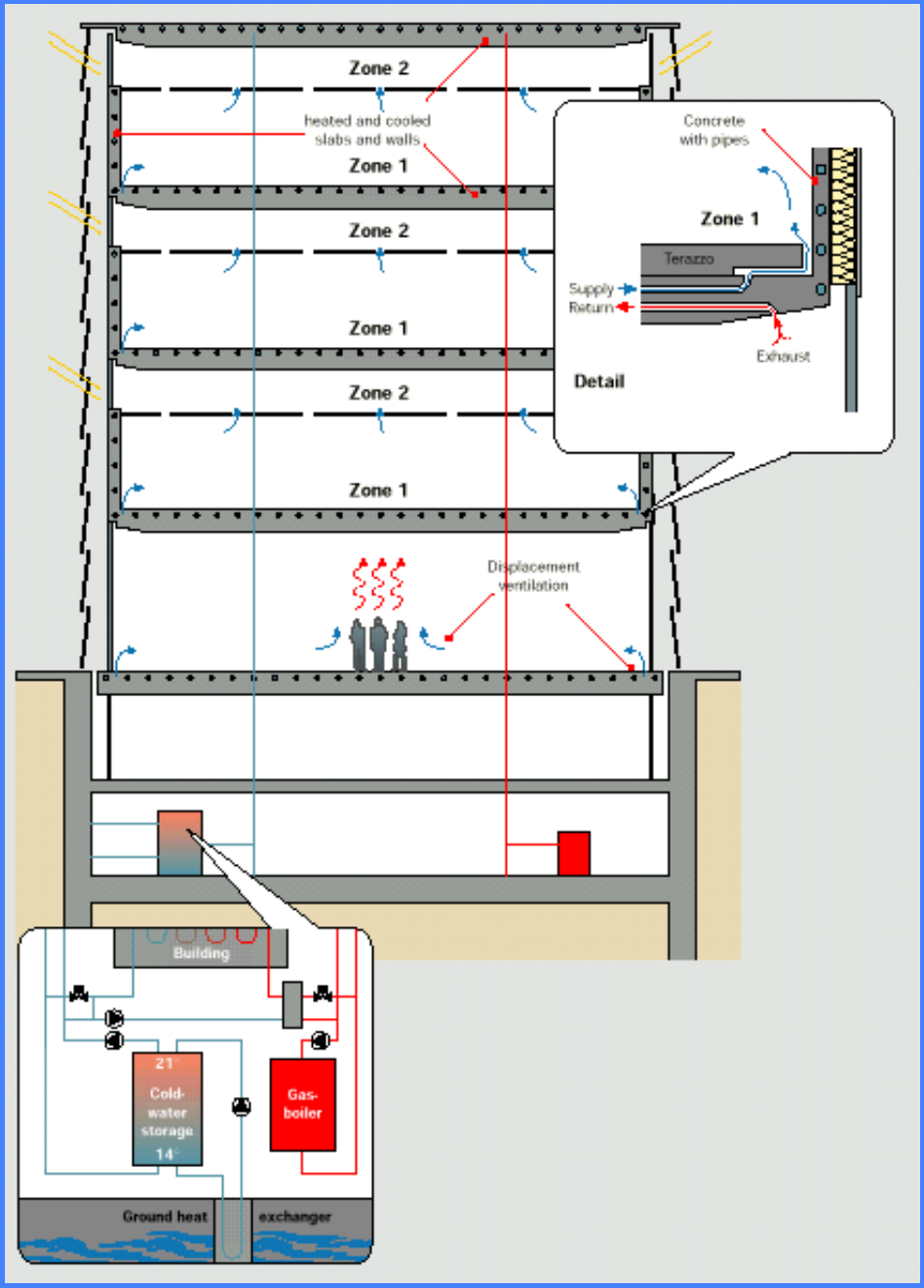


No cooling - decreased performance
Low energy costs
Low operation costs

Constant temperature
Draught
Noise
SBS
High energy costs
High operation costs

Temperature ramps
Reasonable energy costs
Low operation costs

ART MUSEUM BREGENZ

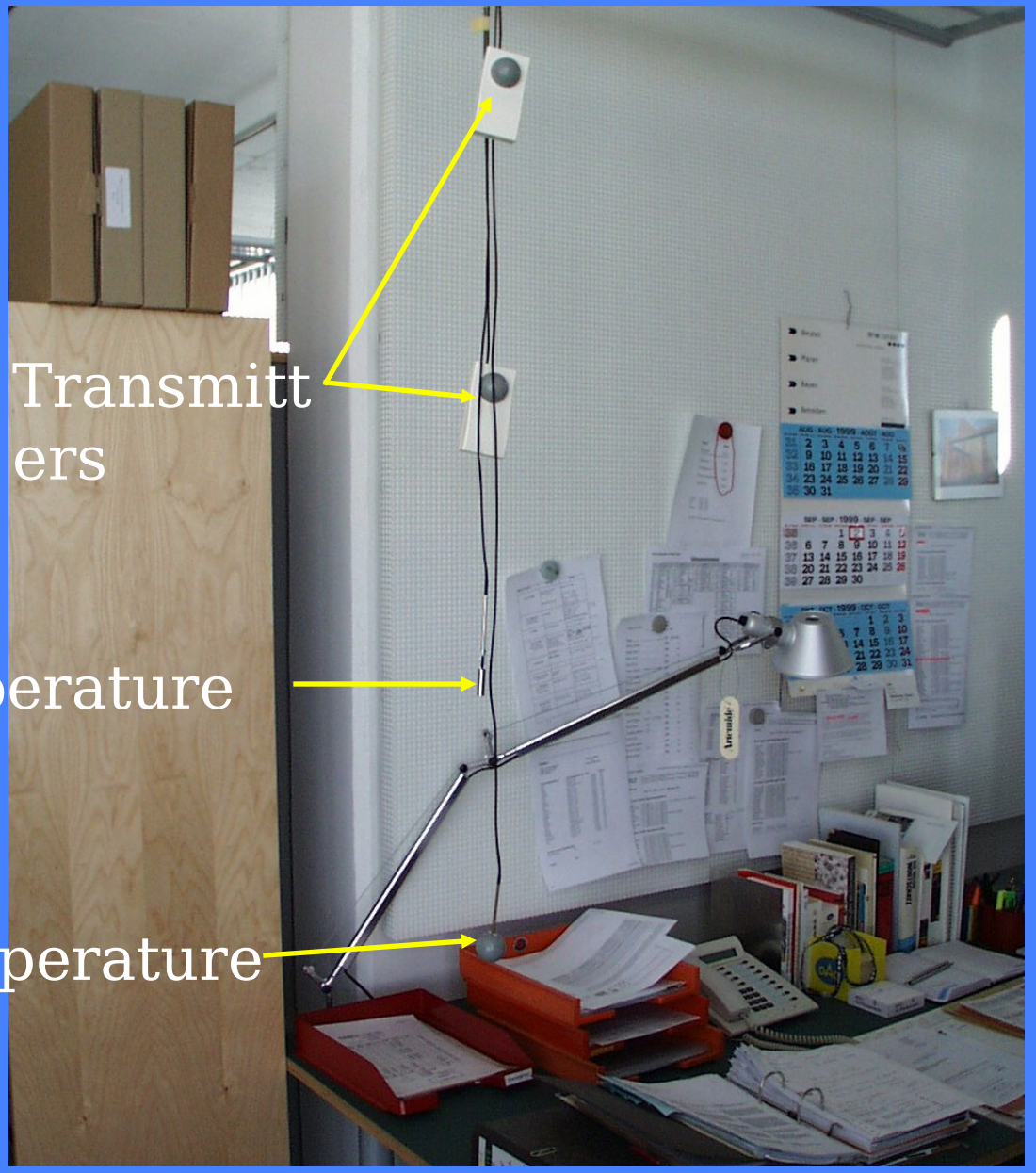


ART MUSEUM BREGENZ

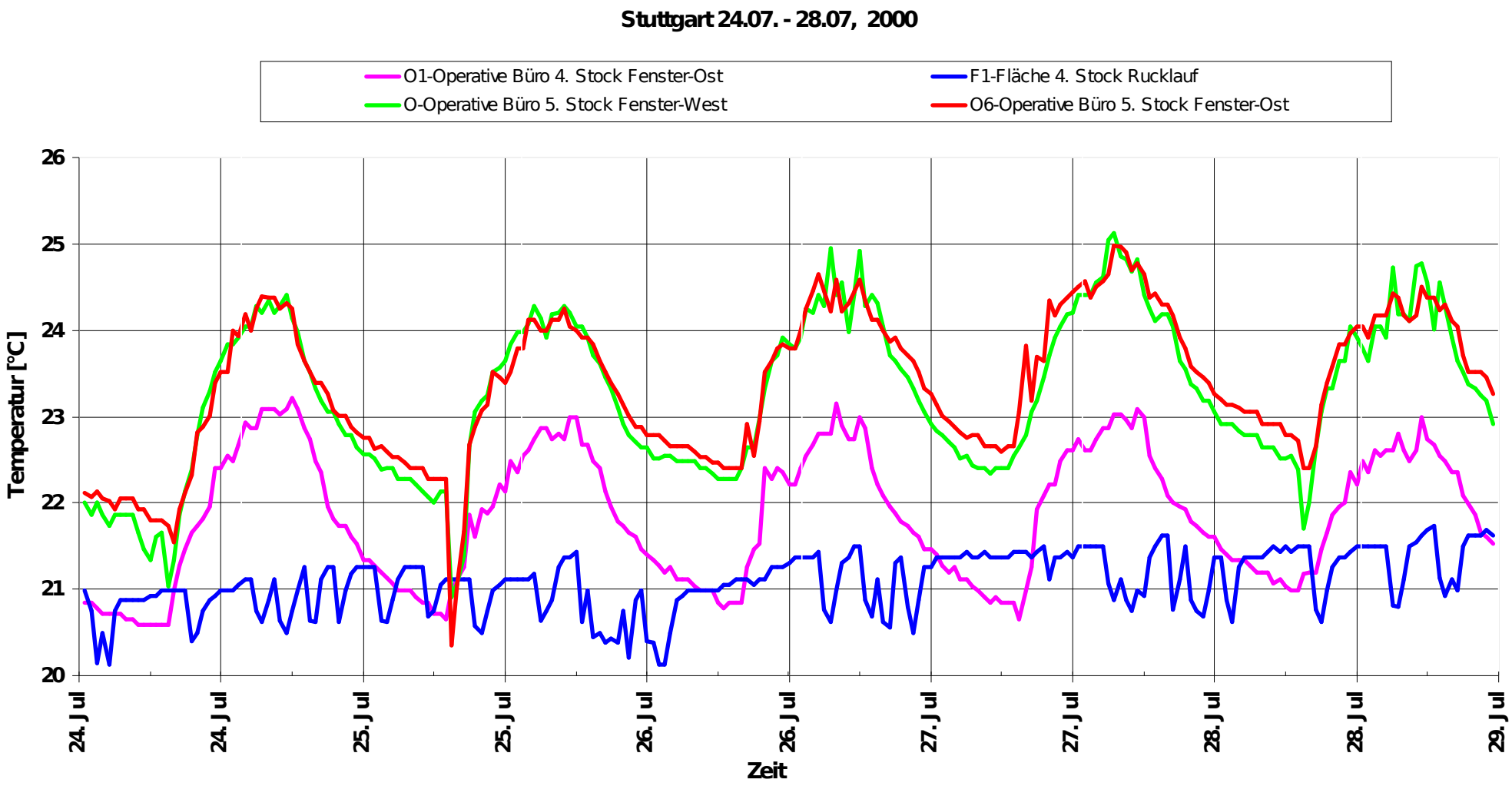
- 3.750 m² floor area
- 4.725 m² embedded pipes
- Condensing boiler
- Ventilation 750 m³/h per floor (first design was 25.000 m³/h

WETEGE

Measurements during normal operation

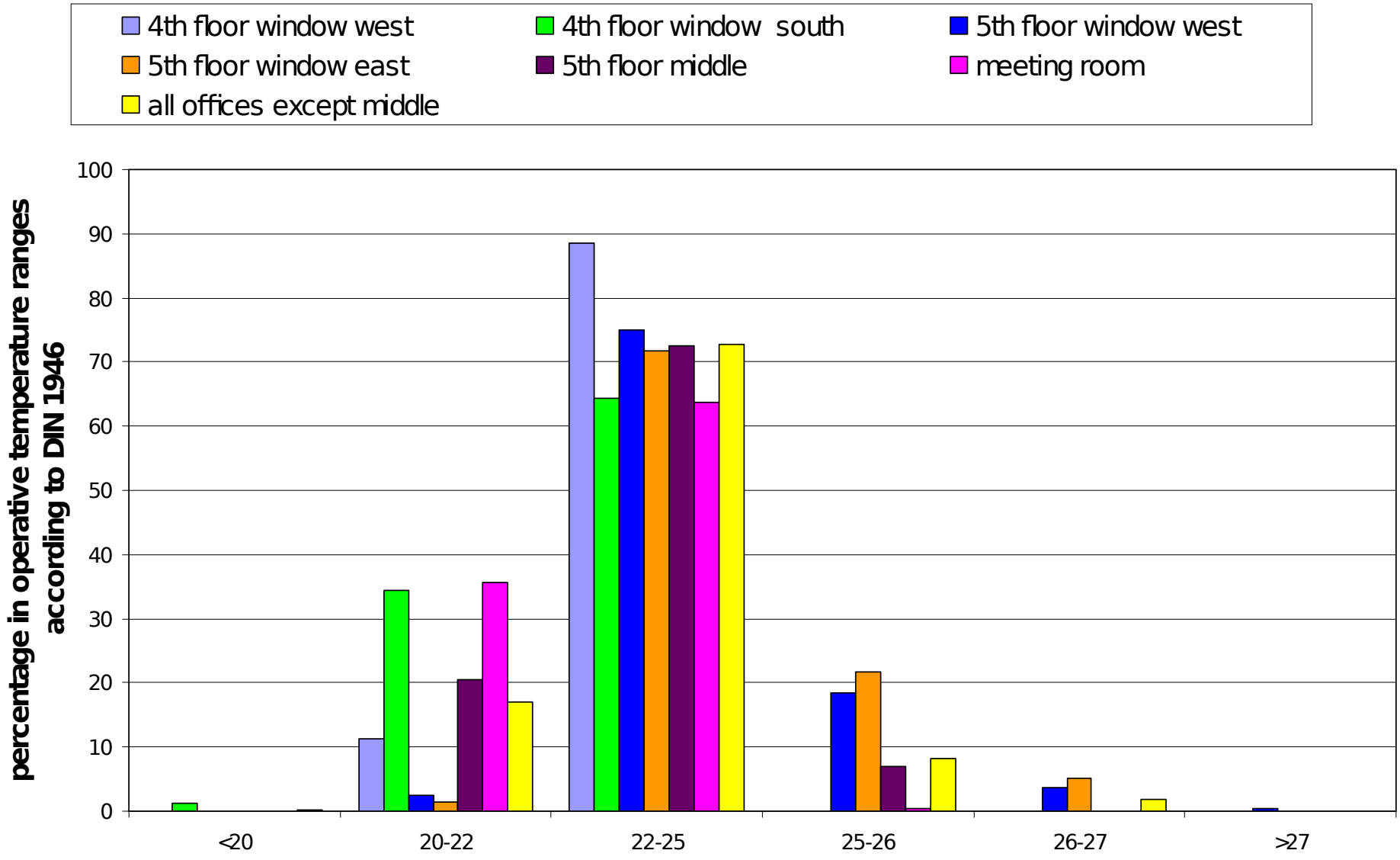


Stuttgart


Stuttgart 24.07. - 28.07, 2000
O1-Operative Büro 4. Stock Fenster-Ost
F1-Fläche 4. Stock Rucklauf
O-Operative Büro 5. Stock Fenster-West
O6-Operative Büro 5. Stock Fenster-Ost
Temperatur [°C]
26
25
24
23
22
21
20
24.Jul
24.Jul
25.Jul
25.Jul
26.Jul
26.Jul
27.Jul
27.Jul
28.Jul
28.Jul
29.Jul
Zeit

Stuttgart

BUILDING 3



PRAXIS

Großobjekt direkt am Main: Allianz-Kai, Frankfurt am Main, 40.000 m² velta contec

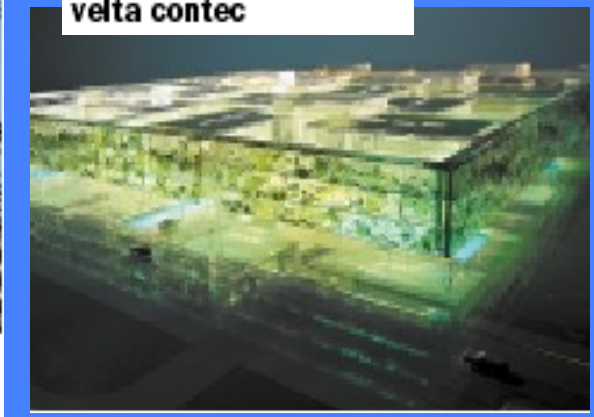
Glaspalast an der ABC-Straße: ABC-Bogen, Hamburg, 7.500 m² velta contec

dvg Datenverarbeitungs-gesellschaft der Sparkassen-Finanzgruppe, Hannover, 24.000 m² velta contec

Tradition in neuen Formen: Geiger 2000, Oberstdorf, 1.200 m² velta contec

VW-Autostadt, Wolfsburg, z. B. Kundenzentrum, 3.500 m² Kühlung über Industrieflächen

Aufgestelztes Gebäude: Bayerische Rückver-sicherung, Unter-föhring, 24.000 m² velta contec



Old and new in Hamburg

Futuristische Architektur über dem Fleet: Berliner Tor, Hambu

Futuristische Architektur: Berliner Bogen, Hamburg, 18.000 m² volta contec

CONCLUSIONS

- **Hydraulic heating/cooling system with pipes embedded in the building structure is an interesting alternative to full air conditioning**
  - **High temperature cooling-low temperature heating**
  - **No noise**
  - **No draught**
  - **Low installation and running costs**
  - **Lower peak load and reduced equipment size**
  - **Lower building height**
  - **Combined with mechanical ventilation**
  - **Reduced capacity?**
  - **Acoustic?**
  - **Latent load?**